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1.— Wigtonshire — Mull of Galloway.

2.— Wigtownshire — Burrow Head.

3.— Western Wigtownshire.

4.— Wigtownshire (East Part).
Kirkcudbright (Portion of Western Division).

5.— Kirkcudbrightshire.

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2 sheets writing paper at beginning.

Memoirs of the Geological Survey,

SCOTLAND.

EXPLANATION OF SHEET
1.

WIGTONSHIRE—MULL OF GALLOWAY.

EDINBURGH:
PRINTED BY MURRAY AND GIBB,
FOR HER MAJESTY'S STATIONERY OFFICE.

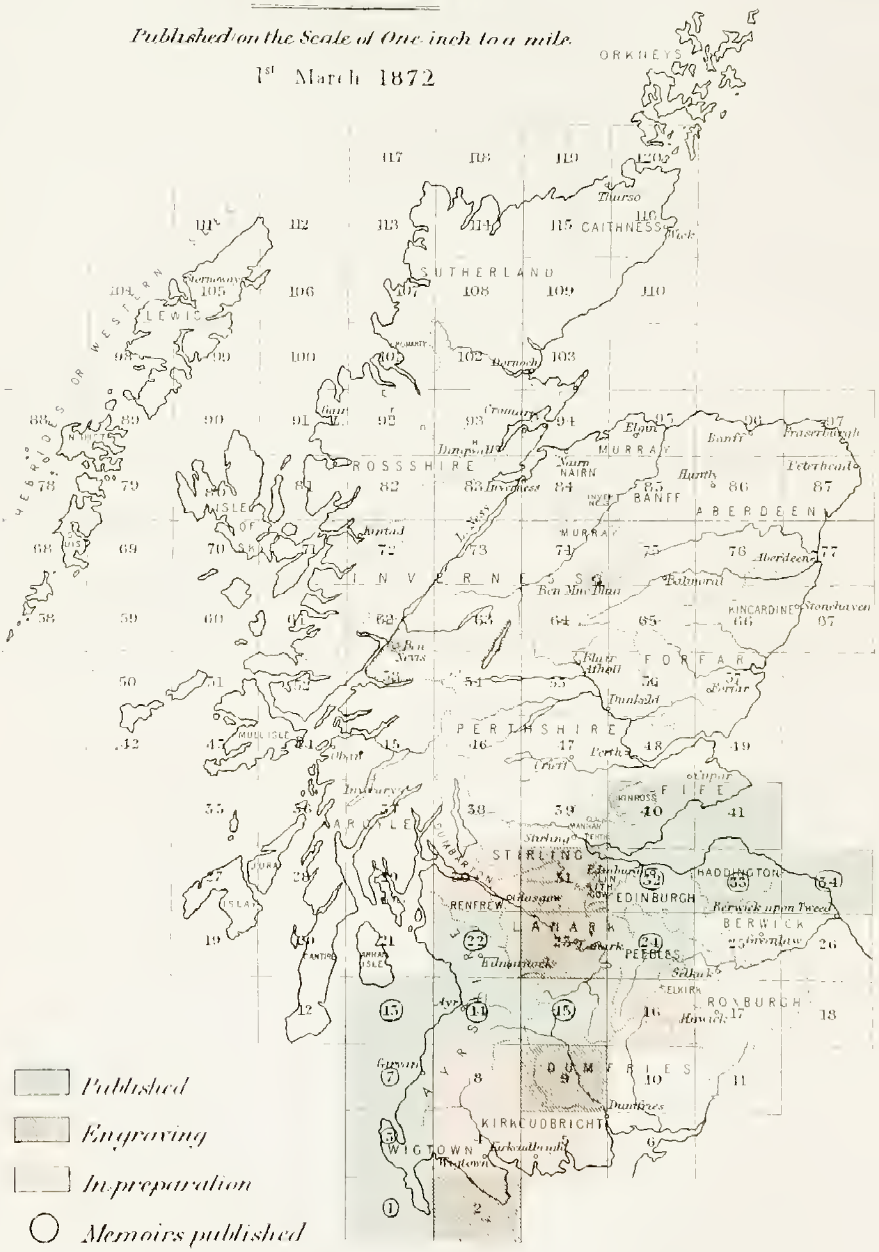
1872.

Price Threepence.

INDEX
to the
GEOLOGICAL SURVEY MAP
of
SCOTLAND

Published on the Scale of One inch to a mile.

1st March 1872



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PREFACE.

The Sheet of the Geological Survey Map which the present Explanation illustrates, was surveyed during the directorship of the late Sir Roderick I. Murchison and under my supervision, by Mr. D. R. Irvine, by whom also this Explanation has been written. The Appendix of Fossils has been prepared by Mr. Robert Etheridge, jun

As the Sheet contains so small an area, and forms geologically and geographically a part of the district to the north, it has not been deemed desirable to do more than merely enumerate as briefly as possible the local features, leaving fuller details regarding the Silurian rocks, with their fossils and intrusive igneous rocks, to be given in the Explanation accompanying Sheet 3.

ARCH. GEIKIE,
Director.

Geological Survey Office,
Edinburgh, *February* 1872.

EXPLANATION OF SHEET 1.

I. AREA EMBRACED IN THE MAP.

1. The present Map contains an area of 21·6 square miles, embracing the southern half of the peninsula which terminates southwards in the Mull of Galloway. This area belongs entirely to the county of Wigtown, and forms the extreme southern promontory of Scotland.

II. FORM OF THE GROUND.

2. As the area represented on the present Map is only a prolongation of the wide Silurian uplands of the south of Scotland, it presents the same general characters by which these uplands are marked, although, from its low elevation and its insular position, it possesses, on the whole, a more cultivated aspect than is to be seen in the higher ground to the north. Most of the surface has been brought under the plough; the more important tracts which still remain in a state of nature being Barncorkrie Moor and Grennan Moor, where, owing to the absence of superficial accumulations, the underlying rocks form rough hills and moorlands. The whole peninsula may be regarded as presenting a long range of precipices to the west, and sloping gradually down to low shores along the eastern seaboard. The western cliffs reach a height of fully 400 feet at Dunman; the highest elevations in the district being one of 525 feet on Cairn Fell, and one of 529 feet on Muntloch Fell. In consequence of the general slope of the ground from west to east, most of the streams flow eastward, but none of them are more than mere brooks. Three prominent depressions interrupt the continuity of the western cliffs, one of these extends across the peninsula from Port Nessock or Port Logan Bay to Terally Bay, the second forms a hollow between Clanyard Bay on the west, and Kilstay Bay on the east, while the third serves as a narrow, slightly elevated neck, to connect the headland of the Mull of Galloway with the rest of the peninsula.

3. The coast line of the present district extends in all to about 23 miles, of these fully 15½ miles are ranges of cliff confined to the west side of the peninsula, except at the Mull of Galloway, where, for a space of two miles, the eastern shores are also precipitous. The low shore, shown on the present Map along the east side of the peninsula, extends for about 7½ miles. Except at the three bays already indicated, there are no sandy beaches on the west side; the full force of the breakers beats there along the base of the cliffs. On the opposite side, however, which lies in the lee of the prevalent south-west storms, flat sandy beaches are continuous almost the whole way.

III. FORMATIONS AND GROUPS OF ROCK ENTERING INTO THE GEOLOGICAL STRUCTURE OF THE DISTRICT.

Aqueous or Sedimentary.

Recent.	Alluvium, Peat. Blown Sand. Raised Beach.
Drift Series.	Sands and Gravels, and Stratified clays. Boulder-clay.
Lower Silurian (Llandeilo).	Greywacke, Shale, etc.

Igneous.

Of Miocene age.	Basalt-rocks in dykes.
Intrusively associated with Lower Silurian rocks.	Granite. Felstone. Diorite.

IV. GEOLOGICAL STRUCTURE OF THE DISTRICT CONTAINED IN THE MAP.

4. The whole of the district embraced in this Map consists of Lower Silurian rocks, pierced here and there by intrusive igneous masses, and overlain with Drift and other surface deposits. As usual these formations are described in ascending order beginning with the oldest.

Lower Silurian.

5. This formation comprises, with the exception of the igneous bosses and dykes, the whole area embraced in this Sheet. The strata consist of greywacke and shale, and, on the whole, are very destitute of fossils. In some thin bands of black shale, however, graptolites are abundant; and they also occur in a thick band of flaggy grey shale, which has been worked for slates at Grennan.

The greywacke is commonly of a grey or greyish-blue colour, occurring in beds of varying thickness, from six inches to six and sometimes eight feet. It is usually much jointed and split up; in many cases the sides of the joints being coated with carbonate of lime or hæmatite. It is thus rendered useless as a building-stone. It varies in texture from a fine-grained mudstone to a coarse gritty sandstone. It is interbedded with partings and beds of grey, greenish, or red shale, usually hard and splintery. At each end of Clanyard Bay there is a band of shattery black shales, which contains some graptolites. These beds are not traceable for any distance, the ground in the line of their strike being entirely covered by drift. A few graptolites have also been obtained from some beds of dark shale at Laggantalluch Head; and a thick band of flaggy-grey shale, running across the country from Kilstay Moor to Grennan slate quarries, has also produced some similar fossils. The above mentioned localities are the only places where Silurian fossils have as yet been found in the tract represented upon this Map. The list given in the Appendix comprises all the species which have been collected.

6. The general strike of the rocks of the district is N.E. and S.W., and the strata are almost always inclined at high angles. From the Mull of Galloway northwards to Port Nessock Bay the beds have a prevailing dip to the north-west; but from the north end of the Bay to the edge of

the Sheet the dip is reversed, the beds being inclined to the south-east; Port Nessock Bay thus forms the centre of a large synclinal trough. There are also various minor folds seen in the section from the Mull of Galloway to Port Logan. Even when the dip is persistent for two or three miles, this need not imply that there is a continuously ascending series of strata for that distance, as the beds may be thrown back upon one another in a number of rapid reversed folds, the tops of which have been removed by denudation, thus bringing the same beds again and again to the surface without a change of dip. From the general sameness of the rocks in lithological character, and the consequent absence of distinctive beds, it is impossible to discover how often such folds may occur; for, even with the help of the shore sections, which are more or less continuous for miles, it is difficult to ascertain with any certainty whether the highly inclined or vertical beds seen in a short distance are all distinct, or may not sometimes be repeated by concealed and quite undiscoverable plications.

7. The Silurian rocks are all of Llandeilo age. This is indicated by their fossils; a list of which, with the localities yielding them, will be found in the Appendix already referred to.

Intrusive Rocks.

8. The Silurian rocks of this district are pierced by numerous intrusive rocks, which occur in two forms. One of these is shown in the large boss of granite, forming a marked feature on the western coast; the other is that of the numerous little dykes and veins sometimes so conspicuous on the coast cliffs.

9. The mass of granite just referred to covers an area of two square miles, extending along the west coast from Laggantalluch Head to the south of Crammag Head. It forms a line of sea-cliffs one mile and a half in length, and sometimes reaching 175 feet in height. This rock varies from dark grey to flesh colour, and from an exceedingly close grain when dark in tint, to a coarse crystalline character when it becomes pink. It consists of orthoclase, quartz, and black mica, with sometimes the addition of hornblende in considerable quantity, and of pyrites more sparingly. These marked changes in its character occur within comparatively short distances. Thus, from Laggantalluch Head south to Portencorkrie it is generally light grey and coarse grained, though sometimes becoming very fine in texture and of a dark grey colour. From Portencorkrie southwards along the coast, it is pink and rather coarse in texture, while on the east margin it is again dark grey and fine grained. Along the north boundary the granite is traversed by numerous quartz-veins running as a rule north and south, at right angles to the line of junction with the surrounding greywacke. The latter is considerably hardened and altered for some distance from the junction. Along the east margin of the granite the greywacke beds are seen abutting directly against it. At Laggantalluch Head, also, the junction of the rocks is well seen.

10. Besides this boss of granite there occur numerous intrusive rocks in the form of dykes and veins. The direction of these usually corresponds with the strike of the beds. The majority are mere veins, consisting of purple, pink, or pale fawn-coloured felstone, having the same character as those in Sheet 3, which lies immediately to the north of the present Map, and in the Explanation accompanying which they will be more fully described. A mass of pale compact fine-grained felstone, sometimes merging into hornstone, fully 200 yards broad, runs across the narrow strip of land which connects the Mull of Galloway with the rest of the peninsula between East Tarbet and West Tarbet Bays. The surface is

much broken up by lines of joints, which, running parallel to the sides of the mass, give it the appearance of bedding—a deceptive character, which is further heightened by the intercalation towards the edge of the mass of thin beds of greywacke and shale. It is owing to the gradual increase of these intercalations that the main felstone mass dies out. It is composed of felspar, with hornblende diffused through it, and some quartz. In some places it contains a considerable quantity of talc. The other dykes shown on the Map are of dark purple or grey felstone and diorite, with the exception of one small basalt-dyke only seen on the shore immediately to the south of Port Logan harbour. These can also be better described in the Explanation to Sheet 3.

Drift.

11. The area embraced in this Map affords abundant evidence of the Glacial Period or Ice Age in this country. This evidence consists of Scratched rock-surfaces, Boulder-clays, Sands and Gravels, and Erratic Blocks.

12. Where the Boulder-clay has been recently removed, exposing the rock surface beneath, the latter is generally seen to be polished, smoothed, and covered with striations, generally very well preserved. Although these striæ have disappeared from the bare mounds and hummocks of rock which have been long exposed to the action of the weather, the characteristic rounded outlines of *roches moutonnées*, or ice-worn rocks, still remain. These rock-hummocks, seen from a little distance, appear perfectly smooth. They are not frequent in this district, owing to the lowness of the land, and the general spread of the Drift deposits over by far the greater part of the area. The general direction of the striæ, which, with one exception, are only seen along the top of the cliffs, is about S.S.W., as will be seen in the Map, where they are all put down in the positions in which they occur. This direction agrees with that of the striæ to the north, shown on Sheet 3, and seems to point to the movement of a large ice-sheet from the high hills to the north-east. The ice must have crossed the head of the Bay of Luce, and mounting over the eastern shore of the peninsula, must have descended into what is now the Irish Channel.

12. The Drift deposits which lie upon this generally ice-worn surface of rock consist here of Boulder-clay, and overlying Sands, Gravels, and Clays. The Boulder-clay, which covers the greater part of this district, has the usual features of the lower part of the Drift in the Silurian tracts of the south of Scotland. It is generally pretty stiff, of a brownish-grey colour, and full of stones, partially rounded and generally covered with striations in the direction of the longer axis of each stone. Some of these stones are of considerable size, but the great majority average from one or two inches to a foot in diameter. They consist almost wholly of the rocks of the district, with a few granite fragments scattered amongst them. This part of the Drift is quite devoid of stratification, though in some places small patches of sand and fine gravel are imbedded in it. At Clanyard Bay, there is a section of Boulder-clay exposed for a depth of fully 100 feet; but the average thickness of the deposit here is perhaps not more than six or eight feet. Shells have been obtained from the cliff of Boulder-clay at Clanyard Bay, a few of them entire, but the majority in a fragmentary condition. There is a sandy patch in the Boulder-clay at the south end of Port Logan Bay, from which shells have also been obtained. The names of the species, with the localities from which they have been obtained, are given in the Appendix.

13. Overlying the Boulder-clay there is a considerable accumulation

of stratified Sand and Gravel, which is spread out over the ground in large patches, seldom rising into ridges or *kames*. It is chiefly confined to the low eastern shore bordering the Bay of Luce, where the ground is much lower than on the other side. Much of these deposits may consist of fragments of ancient beaches which have been left here and there along the shores, but so broken up and irregular from the effects of denudation as to make it impossible now to trace their original form. These sands and gravels have yielded no fossils of any kind. The only example of stratified clays which occurs in this Sheet is at Terally Brickworks, where a small patch of greyish-brown stiff fine clay, containing very few stones and imperfectly laminated, is worked into bricks and tiles. It rests upon the lower Boulder-clay, and contains shells, as shown in the Appendix.

14. The ground embraced in this Sheet has been so long under cultivation, that the larger Erratic Blocks, which may once have existed, have all disappeared. A few small ones may still be seen scattered over the district, along the sides of fields or roads to which they have been carted by farmers when reclaiming the land. These are almost all of grey granite, of the same character as that which forms the higher or Cairnsmore hills to the north-east, from whence they have probably come.

Raised Beach.

15. Although, as just mentioned, some portions of the sand and gravel deposits of the district may represent former sea-margins, only one well-preserved Raised Beach is here to be seen. It can be traced pretty continuously along the eastern seaboard of the peninsula, bordering the Bay of Luce at the height of 25 feet, but never extending inland for more than 150 yards. There are a few fragments of an older terrace at the height of 65 to 70 feet, but they have been very much cut up and worn away by denudation.

Blown Sand.

16. The only Blown Sand on the Sheet is a small patch beside Port Logan. It is being gradually levelled and brought under cultivation.

Peat and Alluvium.

17. Peat is not now abundant in this district; it occurs only in a few small hollows towards the north edge of the Sheet. The largest of these, near Balgown Farm, has been drained and brought under the plough, and in a few years will be hardly distinguishable from the surrounding soil. The other patches are also being reclaimed, none of them having a sufficient thickness of peat to be worked for fuel.

18. The Alluvium, as will be seen on the Map, consists of small patches along some of the larger streams; and the beach of sand, mud, and shingle, exposed at low tide, along the east shore of the Map.

V. ECONOMIC MINERALS.

19. *Building-stone.*—A few of the least jointed greywacke beds in this district are quarried for Building-stone; but the great majority of the rocks are too much jointed and broken to be of use for any building purpose except making 'drystone' dykes. The granite shown on the Map has been quarried near the farm of Low Slock, and at other places, but only to a very limited extent. It would form a good building material if properly opened up. At Grennan and Kilstay Moor a band of grey flaggy shales has been quarried for roofing slate. There are, however, no true slates in the district, none of the beds being traversed

by cleavage, but splitting along the lines of bedding. The shales are too soft and coarse to be employed, except merely for local use.

20. *Road-metal.*—The common greywacke rock of the district is largely used for Road-metal, for which it is very suitable on account of its hardness and toughness. The granite also is available for causeway-stones; but it has not yet been used for this purpose.

APPENDIX.

A.—LIST OF LOCALITIES

FROM WHICH FOSSILS HAVE BEEN OBTAINED BY THE GEOLOGICAL SURVEY IN SHEET I.

1. North end of Clanyard Bay, 2½ miles N.W. of Drummore.
2. South end of ,, ,, ,,
3. Grennan Slate Quarry, 2 miles N. of Drummore.
4. Kilstay Farm, Quarry near, 2 miles N. by W. of Drummore.
5. Laggantalluch Head, Cliffs 250 yds. N. of, 3 miles W. of Drummore.
6. Terally Brickworks, 3 miles N. of Drummore.
7. Port Logan Bay, Cliffs S. end of, 4 miles N.W. of Drummore.

B.—LIST OF FOSSILS

OBTAINED BY THE GEOLOGICAL SURVEY FROM THE DISTRICT EMBRACED IN SHEET 1.

Lower Silurian.

		Localities.
Hydrozoa,	Diplograptus pristis.—*His.*	1, 2, 5.
	,, ,, var.[*]—	1.
	,, tamariscus.—*Nich.*	5.
	Graptolithus convolutus.—*His.*	2.
	,, (discretus ?—*Nich.*)	2.
	,, latus.—*M'Coy.*	3.
	,, lobiferus.—*M'Coy.*	2.
	,, (Nilssoni ?—*Barr.*)	2.
	,, Sedgwickii.—*Portl.*	2.
	,, tenuis.—*Portl.*	1.
	,, *Sp.*	3, 4.
	Rastrites maximus.—*Carr.*	1.
	,, peregrinus.—*Barr.*	1.

---

[*] Four specimens of this variety were noticed, having all the characters of *D. pristis*, but with the axis at the distal end much inflated, one especially so. Dr. Nicholson considered this to be a distinct species, under the name of *Diplograptus vesiculosus* (*vide Quart Jour. Geo. Soc.*, vol. 24, p. 527; also *Monograph on British Graptolitidæ*, pp. 40, 41). On the other hand Mr. Carruthers retains it in the normal species *D. pristis* (*Geol. Mag.* vol. v., p. 130).

Drift.

(*a*) BOULDER-CLAY.

Lamellibranchiata, .	Astarte sulcata.—*Da Costa*	. 7.
	,, ,, var. elliptica.—*F. and H.*	1.
	Cyprina Islandica.—*Linn.*	.
	Tellina solidula.—*Pult.*	. 1, 7.
	Leda (*like* pernula.—*Müller.*) . . .	. 7.
	Saxicava rugosa.—*Linn.* . . .	. 7.
Gasteropoda,	Turritella terebra.—*Linn.* .	1.

(*b*) LAMINATED CLAY.

Foraminifera, . .	Polystomella striato-punctata.—*F. and M.*	6.
Entomostraca, . .	A few single valves much worn,	6.
Lamellibranchiata, .	Leda pygmæa.—*Münster*,	. 6.
	,, truncata.—*Brown.* . .	6.

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EXPLANATION OF SHEET
2.

WIGTOWNSHIRE—BURROW HEAD.

EDINBURGH:
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1873.

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to the
GEOLOGICAL SURVEY MAP
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SCOTLAND

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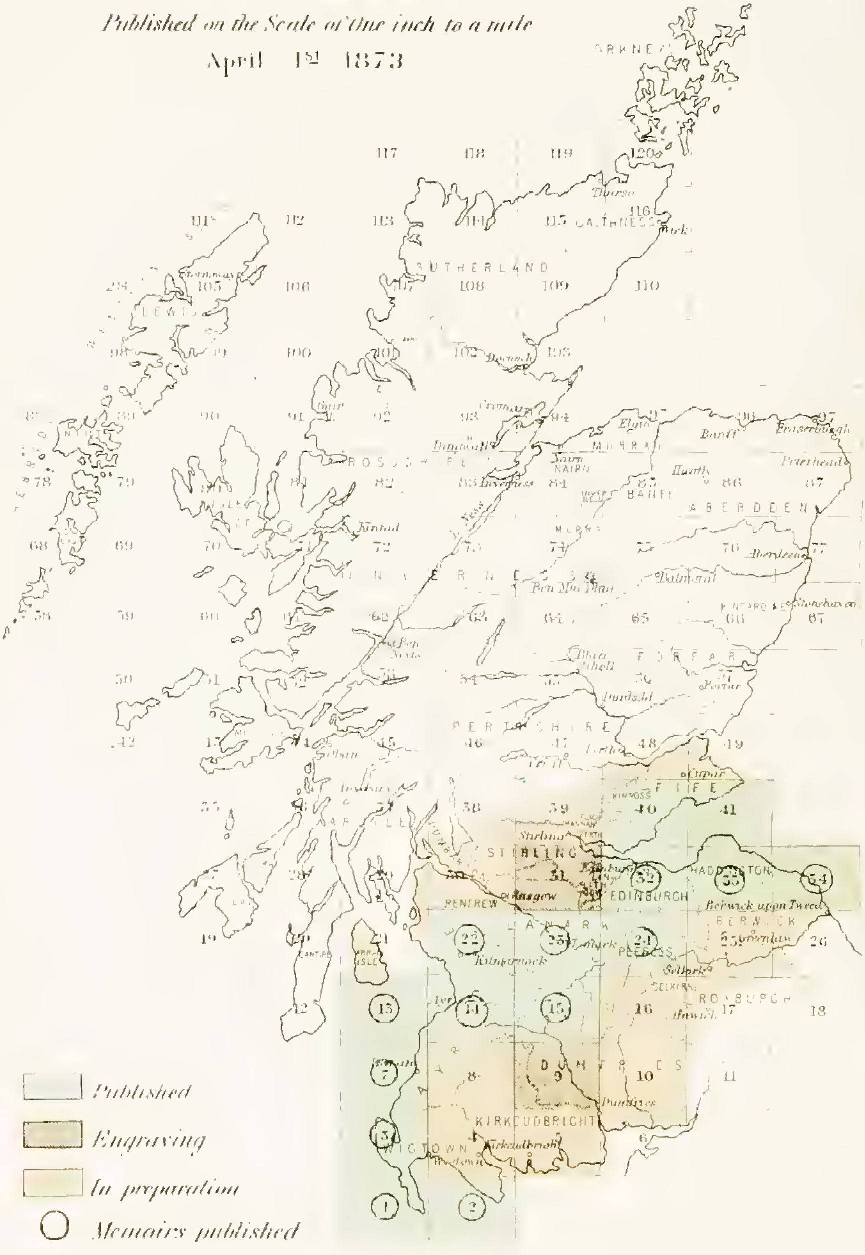

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WIGTOWNSHIRE—BURROW HEAD.

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1873.

PREFACE.

THE Map illustrated by the present Explanatory Memoir was surveyed geologically, under my supervision, by Mr. James Craik, partly during the directorship of the late Sir Roderick Murchison, and partly under that of the present Director-General, Professor Ramsay. During the progress of the work, I frequently assisted in the mapping; and after it was completed, I requested Mr. John Horne, who had been engaged in the Kirkcudbright area, to visit the coast sections, with the view of correlating the Wigtownshire rocks as far as possible with those the order of which has been made out by the Geological Survey in the counties lying further to the north-east. The suggestion that the anticlinal axis, noticed in par. 5, is the main axis of the Silurian tract of the south of Scotland, and consequently that the strata along its line are somewhere about the base of the Scottish Lower Silurian Series, is due to Mr. Horne. Probably more precise information may be obtained during next year, when the area lying to the east of Wigtown Bay is surveyed.

The Explanation has been written by Mr. Craik, with the exception of paragraphs 5, 6, 10, 11, and 15, which have been supplied by myself.

The list of Fossils given in the Appendix has been prepared by Mr. R. Etheridge, by whom the specimens were determined.

ARCH. GEIKIE,
Director.

GEOLOGICAL SURVEY OFFICE,
EDINBURGH, *December* 1872.

EXPLANATION OF SHEET 2.

I. AREA EMBRACED IN THE MAP.

1. The present Sheet of the Geological Survey Map of Scotland represents that part of the county of Wigtown which forms the promontory ending in Burrow Head. It contains portions of the parishes of Whithorn, Glasserton, Sorbie, and Mochrum, and embraces an area of 32 square miles.

II. FORM OF THE GROUND.

2. Like the rest of the lower parts of the county of Wigtown, the district now under description consists generally of gently sloping ridges, separated by lower rocky tracts, the direction of both ridges and hollows having a pretty uniform trend from north-east to south-west. As a whole, the ridges rise towards the south-west, and attain, as they approach the coast-line on that side, their highest elevations. Thus, the ridge of Slate Heugh and Fell of Carleton reaches a height of 479 feet over the sea, terminating in a bold rocky hill close to the south-western coast. Again, further inland, and to the north-west, the Fell of Barhullion attains a height of 449 feet. Most of these higher ridges have a rocky surface, and are devoted to pasture. The arable land lies mostly on the lower grounds and on the ridges of clay, although some tracts where the rock protrudes almost everywhere above the surface have nevertheless been brought under the plough.

3. The streams are numerous, but none of them flow for more than two or three miles. They are consequently of small size, and, indeed, throughout many parts of the district they flow in artificial channels as mere ditches. It is noteworthy that the larger streams run transversely to the general trend of the ridges and hollows, as, for example, the Ket and the Drummullin Burn, while the smaller runnels flow longitudinally between the ridges. As the land rises towards the south-west, the coast-line on that side of the promontory is higher than on the other side. It consists alternately of steep rock-cliffs and of green slopes of boulder-clay. The loftiest cliffs of rock are those which range round Burrow Head to Cairnhead, since they here and there reach a height of 150 feet. The best marked boulder-clay slopes extend from the Point of Lag south-eastwards to Portcastle Bay.

III. FORMATIONS AND GROUPS OF ROCK ENTERING INTO THE GEOLOGICAL STRUCTURE OF THE DISTRICT.

Aqueous.

		Sign on Map.
Recent.	Alluvium, Peat, ...	-v-
	Blown Sand, ...	(brown dots).
	Raised Beach, ...	⌣⌣

		Sign on Map.
Drift Series.	Erratic blocks. Sands, Gravels. Boulder-clays.	
Lower Silurian.	Greywacke and Shale, . . . (probably of Llandeilo age).	b^2

Igneous.

Intrusive.

Dykes of Felstone, etc., ...	F

IV. GEOLOGICAL STRUCTURE OF THE DISTRICT EMBRACED IN THE MAP.

Lower Silurian.

4. The area contained in this Map forms a part of the great Lower Silurian tract of the south of Scotland. From the want of fossils, and of any recognisable lithological features, it is as yet impossible to decide precisely to what portion of the Silurian system the strata belong. They are provisionally referred to the Llandeilo series.

5. From the work which has now been accomplished by the Geological Survey in the wide region between Wigtownshire and the uplands of Berwickshire, it is probable that the rocks which are now to be described belong to the bottom beds of the Lower Silurian series of the south of Scotland. Certain well-marked zones have been traced for great distances, almost completely across the country, and these retain a notable parallelism with each other and with the prevalent south-west and north-east strike of the rocks. It has long been understood that an anticlinal axis traverses the Silurian rocks of the southern counties, and its position in the central and eastern tracts was indicated by Professor Harkness as far back as the year . From Eskdalemuir it strikes south-westward, keeping to the north of Lockerbie, and stretching thence by Dumfries through Galloway. There is reason to believe that it is this major axis which runs through the eastern headland of Wigtownshire, as described in paragraph 6. In that case, the rocks which rise along its line should be the oldest in the district, and should agree in general characters with those which occur along the same line towards the north-east. And this appears to be the case.

6. Throughout the whole district there is great uniformity of character among the Silurian strata. They consist of hard, well-bedded greywacke, of various shades of grey and blue, occasionally of red, and usually separated by partings or thicker layers or beds of hard fissile shale. Alternations of these two varieties of rock extend throughout the whole of the district. No very satisfactory structure has yet been made out among these strata. They strike from north-east to south-west, dipping usually at high angles. An anticlinal axis, referred to in the preceding paragraph, corresponding with the general strike, extends across the peninsula from near the old castle of Carghidown to the opposite coast-line about Cairnhead. So far as at present made out, the lowest rocks of the district rise to the surface along this axis, and appear to be a prolongation of the axial beds from Kirkcudbright. The rocks at Burrow Head, on the one side of the fold, are probably the same as those about Cruggleton Point on the other. In spite of numerous minor folds, there is probably, on the whole, an ascending section towards N.W.; for when

we pass into Sheet 4, the line of the black anthracitic graptolitic shales is met which runs from Drummore, near the Mull of Galloway, northeastward across the Bay of Luce, re-appears to the south-west of Wigtown, and sweeps in a remarkably straight line through Kirkcudbright and Dumfriesshire, by Moffat and Ettrick, to Melrose.

7. The greywackes and shales of the present district exhibit much contortion, faulting, and occasional cleavage. These features may be seen to great advantage along the coast sections, as at Burrow Head and along the cliffs to the north of the Isle of Whithorn, and still more markedly between Portyerrock and Port Allan. From the number of anticlinal and synclinal folds seen on the coast-line, it is evident that, in spite of the high angles everywhere visible in the interior, the real thickness of rock is not so great as might at first sight appear, since the same beds are repeated again and again by folds. Although the rocks have undergone so much contortion and pressure, cleavage is neither abundant nor, on the whole, well marked among them. It occurs most markedly about the line of the great anticline. The best examples of this structure noticed in the course of the survey occur on the Fell of Carleton. In one or two places, where the beds have been thrown into minor curves, a set of cleavage planes, dipping at angles of from 70° to 80° towards the north-west, traverse the shales, where they are tolerably well defined, but cease as they pass into the interstratified bands of greywacke. Their direction remains persistent, and unaffected by the contortions through which they pass.

8. In those places where the rocks have been much contorted and broken, veins of carbonate of lime, barytes, and other minerals occur. One of the best developed of these veins has been formed along a line of fault which runs W. 15 N., on the shore at Tonderghie. In addition to barytes, calc-spar, and quartz, this vein contains iron and copper pyrites. As already remarked, no fossils have been met with in any part of the Silurian rocks of the district. But as the greywackes and shales agree in lithological characters with those on the same line of strike further to the north-east, they are, together with these, provisionally referred to the Llandeilo series. Further light, however, may be expected to be thrown upon the present small district by the extension of the work of the Survey in Kirkcudbright.

Intrusive Rocks.

9. Throughout the district the Silurian rocks are traversed by various intrusive masses. These always occur in the form of dykes or of veins, usually parallel with the general strike of the rocks, though in many cases transverse to it. They appear most abundantly on the coast-line, since the rocks are much more continuously seen in section there. There can be little doubt, however, that though less frequently seen, owing to drift, peat, and other surface materials, they must also be abundant in the interior. A fact which has been already frequently remarked in the course of the work of the Geological Survey is also noticeable here—namely, that the dykes are apt to occur in clusters, with wide spaces between in which none can be traced. As a rule, they are exceedingly short; only in one instance has it been possible to trace one of them for a length of about three-quarters of a mile. In most instances, especially in the interior, a dyke cannot be followed with any certainty beyond the boss of rock on which it is first seen.

10. Petrographically, the dykes offer many points of interest, though, at the same time, they present many difficulties in the way of a precise nomenclature, owing to the great extent to which they have undergone

internal alteration and the more or less complete disappearance of part or the whole of their original minerals. They may be ranged under three groups. 1st, Felstones—rocks having a compact orthoclase base, and with few crystals of other minerals. 2d, Rocks having a similar base, but containing sometimes abundance of plates of foliated talc, occasionally mica; these might be called talcose felstones. 3d, Rocks in which the base is that of felstone, through which are scattered abundant crystals of hornblende, usually with talc and, less frequently, black mica. Occasionally crystals of striated felspar and of diallage make their appearance. For such rocks it is difficult to find a name in the present nomenclature of petrography. At one moment they might be termed syenites; but as the hornblende is replaced by talc or mica, that name ceases to be appropriate. Throughout all these three groups, black opaque specks and cubical crystals of pyrite are visible under the microscope, sometimes so abundantly as to form a considerable proportion of the rock. It may be added that this sulphide appears to have been the most indestructible of the minerals in the dykes, seeing that while the felspar crystals have been greatly defaced, and the original hornblende has passed into talc, the pyrite cubes remain sharp and unchanged.

11. Examples of the first group occur at different parts of the coast section, as at Burrow Head. Of the second, at St. Ninian's Cave, near Whithorn; Stirnie Burn, half a mile north from Whithorn; at Portyerrock, and many other places. Of the third, at Morrach Shore, Cairnhead (this is microscopically a singularly beautiful rock, from the perfection of the hornblende crystals), Cairndoon Plantation, etc.

Drift.

12. Traces of the movement of the ice of the Glacial Period are found over the whole of the district represented on the present Map. The usual evidence is observable in ice-worn rocks, boulder-clays, and erratic blocks. There occur also deposits of sand and gravel.

13. *Ice-worn Surfaces of Rock.*—Wherever the rocks are exposed in the interior, they bear the characteristic impress of ice-action in the flowing outlines of crag and hollow. Owing to the nature of the greywacke and shale, and the facility with which they are acted on by the weather, the finer markings sculptured by the ice are usually effaced from the weathered surfaces. Yet the knobs of rock throughout the district still show the unmistakeable contour of *roches moutonnées*, of which the longer axes usually point in a general south-westerly direction, nearly parallel to the strike of the beds. Wherever a surface of rock has been recently bared of boulder-clay, it is seen to retain the finer striæ and groovings. Some good examples may be seen, in the centre of the Map, on the farm of Broompark, where the striæ point W. 42 S. The direction of the grooves and of the *roches moutonnées* indicates the movement of the ice from the range of high grounds to the north-east.

14. *Boulder-clay.*—One of the most striking features in the distribution of the drift in this district is the manner in which the boulder-clay is scattered over the ground, in large, oblong, smooth ridges, to which the name of 'drums' is locally given. As these ridges are always cultivated, while the surrounding lower ground consists often of bare rock, peat, and heather, the contrast between these mounds of drift and the barren ground around them strikes the eye at once. Throughout the present district the general direction of the longer axes of these drift-mounds is about north-east. In many cases the bottom of the drum is the limit of the drift, the bare ice-worn rock coming out sharply from underneath. But the boulder-clay is also abundantly scattered through many of the hollows.

It appears, indeed, to have been at one time somewhat more thickly distributed over these low grounds than it is now, since scratched stones, evidently once a part of the boulder-clay, are found on rocky slopes, mingled with the angular *debris* of the weathered rock.

15. The *drums*, however, are not due merely to denudation, though their outlines may have been thereby greatly modified. We find them, for example, rising sharply from the margin of a lake, the bottom of which, when drained, shows a wide expanse of bare, ice-smoothed rock (as at Dowalton Loch, in Sheet 4). Had the *drums* been merely remnants of a once continuous sheet of boulder-clay, these hollows would necessarily have been filled up with the detritus. Moreover, they lie in irregular strips or bands, corresponding generally with the direction of the striæ on the rocks. This is not so well shown in the present Map as in that to the north. These Wigtownshire *drums* appear to be identical in character and origin with the Irish *drumlins*.

16. Some of the thickest masses of boulder-clay in the district occur on the shore, on either side of the Fell of Carleton, where they rise to a height of more than 200 feet above the sea. This deposit is usually reddish, with the ordinary stiff unstratified character. Sometimes it contains interstratified beds of gravel and sand, as on the side of a cliff to the south of Glasserton Hill, in a section on the roadside west of Monreith village, and at the Monreith tile-works. At the latter place there is an upper reddish-brown, rather friable, clay, containing many scratched pieces of greywacke, and a lower stiff blue clay, with few stones. The latter deposit contains shells, usually in a fragmentary state. (See Appendix.)

17. *Sands and Gravels.*—Besides the intercalated strata already referred to as occurring in the boulder-clay, sand and gravel are found in several places covering the clay. Caps of gravel lie on some of the hills in Monreith Park, and sand is found on the top of the slopes to the east of Monreith Village. A similar deposit has been ridged into the kame shape, on which stands the old camp of Laggan, between Carleton Fell and the Hill of Glasserton ; and another to the east of Whithorn, on the farm of Portyerrock. The most prominent sand and gravel deposit in the district, however, lies on the farm of Arbrack, and is crossed by the road from Whithorn to Isle of Whithorn. Its summit is upwards of 125 feet above the sea level. It consists of inclined beds of fine sand, with alternate layers of gravel of various degrees of coarseness. The stones generally consist of blue and grey greywacke, grit, and shale, grey granite, and decomposing micaceous schist. No shells appear to have been found in this deposit, the only organic relic it has yielded being a large piece of amber, which was found, several years ago, deeply imbedded in the gravel. Some portions of the gravel have been cemented together into a conglomerate by carbonate of lime, probably from the decomposition of shells.

18. *Erratic Blocks.*—These occur over the greater part of the district, resting sometimes on drift, sometimes on bare rock. They consist chiefly of granite, but blocks of grit, greywacke, and felstone occur among them. The largest observed is one of granite, containing nearly 200 cubic feet. It is called the 'Wren's Egg,' and lies on a gravel deposit about 125 feet above the sea, near Monreith. Many boulders are yearly cleared off the surface by the farmers, and may be seen filling up old quarries, or lying in heaps in the corners of the fields. Those of granite are often used for building purposes. Although more abundant in some localities than in others,—as, for example, on the farms of Claymoddie, Dinnans, and Drummaston, and in the neighbourhood of Monreith,—they have been pretty generally distributed, even to the extreme southern edge of the promon-

tory, where one of granite, containing 35 cubic feet, lies at a height of 150 feet above the sea, at Burrow Head. There can be no doubt that these boulders have travelled from the granite hills to the north-east.

Raised-Beaches.

19. Although the coast-line of this promontory is exposed to a heavy sea, portions of a former sea margin have been preserved on the south-west side. On some parts of the coast-line which consist of boulder clay, a terrace has been cut out of that deposit at a time when the land was from 40 to 50 feet lower than it is at present. The largest fragment of this terrace now to be seen in the district extends for about three miles from Port Counan to Cairndoon. Its surface is very shingly, though at its north-western end it has been to some extent cultivated. Another fragment runs northwards from the village of Monreith.

Blown Sand.

20. Only at one part of the coast-line does blown sand form any marked feature. At the Point of Lag, it rises into a hill 75 feet above the sea. North-west from Monreith it is sparingly spread over the slopes of boulder-clay.

Peat and Alluvium.

21. Before cultivation had changed so many of the features of the district, most of the hollows, and to some extent even the slopes of the hills, appear to have been covered with peat. Even now, along those rocky tracts which have not been brought under the plough, peat is usually found covering the bottoms. But as farming operations extend, more and more of the peat is ploughed up, and in a few years it becomes difficult to ascertain what were its former boundaries. The largest peat-moss in the district is the Whithorn Moss. Another of smaller size lies a little further west, on the farm of Barmeal.

22. The streamlets of the district have hardly any alluvium along their courses. At one time, however, there must have been many lakes in this part of the country, lying among hollows of rock and drift. These lakes have almost wholly disappeared, their sites being marked now by flat tracts of alluvium. Large trunks of oak and other trees are taken out from the peat-mosses and these alluvia. A stone celt was ploughed up on the farm of Chapelheron, to the north of Whithorn. It was formed of one of the hard altered shales of the district, and had acquired the white crust so often assumed by stones which have lain long under peat.

V.—ECONOMIC MATERIALS.

23. *Building Materials.*—The chief stone employed in building is the ordinary greywacke of the district. Owing to the number and irregularity of the joints, however, it is not well adapted for its purpose. The corner-stones are frequently of granite, obtained from boulders, though considerable quantities of this stone now come from Dalbeattie. Red sandstone is also used for the facings of door-ways and windows, and occasionally for flags; but it is obtained from Whitehaven, whence also comes a white freestone which is used to some extent in this area. The field-dykes and walls are also built of greywacke, though occasionally granite and other boulders are built into them, and in the vicinity of felstone dykes detached blocks of these igneous rocks are used.

24. *Road-metal.*—The common greywacke of the country is employed

or road-making, but owing to its rapid weathering it forms a bad material for this purpose, and the substitution for it of some of the harder igneous rocks would be of great advantage to the traffic on the roads.

25. *Metals.*—Traces of iron and copper occur in the more southerly parts of the district, the iron usually as chalybite, the copper as copper pyrites. The vein already mentioned as occurring at Tonderghie has been worked to some extent, but never to any profit. With this exception there have been no workings, owing to the small quantity in which the metals occur.

26. *Fuel.*—The only fuel supplied by the district is the peat which is brought from Whithorn Moss, before alluded to. It is rarely of good quality, yielding a large quantity of dusty ash, and being in many places of a pale colour and earthy, when it is here called 'flow.'

27. *Soils.*—The decomposing greywackes and shales of the district generally form a soil which is warm and quick. That which is underlaid by till has usually what is called a 'cold bottom.' The soils formed of weathering rock chiefly occupy the south, west, and south-west portions of the area, with a considerable part of the centre. The boulder-clay soils occupy a great part of the north, north-east, and north-west, and east and south-east portions. The distribution of the gravels has been already alluded to. They form a good soil when rain is plentiful, but in a dry season cause trouble and loss.

28. The Scare Rocks, which are included in this Sheet, are about 8 miles, in a west-south-westerly direction, from Monreith. They consist of several small rocks in cluster, and a larger rock at a distance of three-quarters of a mile from the small group. These rocks consist of thick-bedded hard grey greywacke, with red and grey shaly partings. The strike is E. 30 N., and the dip varies from 65° to 85° to N.W. The 'Big Scare' is crossed by two dykes of dark-coloured felstone, with hornblende, and two of the smaller rocks are crossed by a dyke of like character. The extreme length of the large rock is 180 yards.

APPENDIX.

As mentioned in the Memoir, no Fossils have been obtained from the Lower Silurian rocks of the district. The only organic remains yet noticed occur in the superficial deposits referred to in par. 16. In the clay beds of the Monreith Tile-works remains of broken shells are not infrequent, the only form recognised in the collections made by the Survey being a *Leda*. By washing the clay from that locality, three genera and four species of Foraminifera and a few valves of Entomostraca were obtained. Many of the Foraminifera have a very starved appearance. The Entomostraca have been kindly determined by Mr. G. S. Brady.

LIST OF FOSSILS FROM THE GLACIAL DEPOSITS.

Lamellibranchiata	Leda, sp.	
	Fragments of shells.	
Foraminifera	Nodosaria humilis.	*Roemer.*
	Nonionina depressula.	*Walker and Jacob.*
	Polystomella striatopunctata.	*Fichtel and Moll.*
	Quinqueloculina sp.	
Entomostraca .	Cythere emarginata (?).	*Sars.*
	Cythere pulchella (?).	

IV.—Vertical Sections. *3s. 6d. per Sheet.*

Sheet 1. Edinburgh Coal-field.
„ 3. Kilmarnock Coal-field.

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,, 4. Ayrshire Coal-fields (west side).
,, 5. Ayrshire Coal-fields (east side).

[*List of Publications continued on page 3 of cover.*

Memoirs of the Geological Survey,

SCOTLAND.

EXPLANATION OF SHEET

3.

WESTERN WIGTOWNSHIRE.

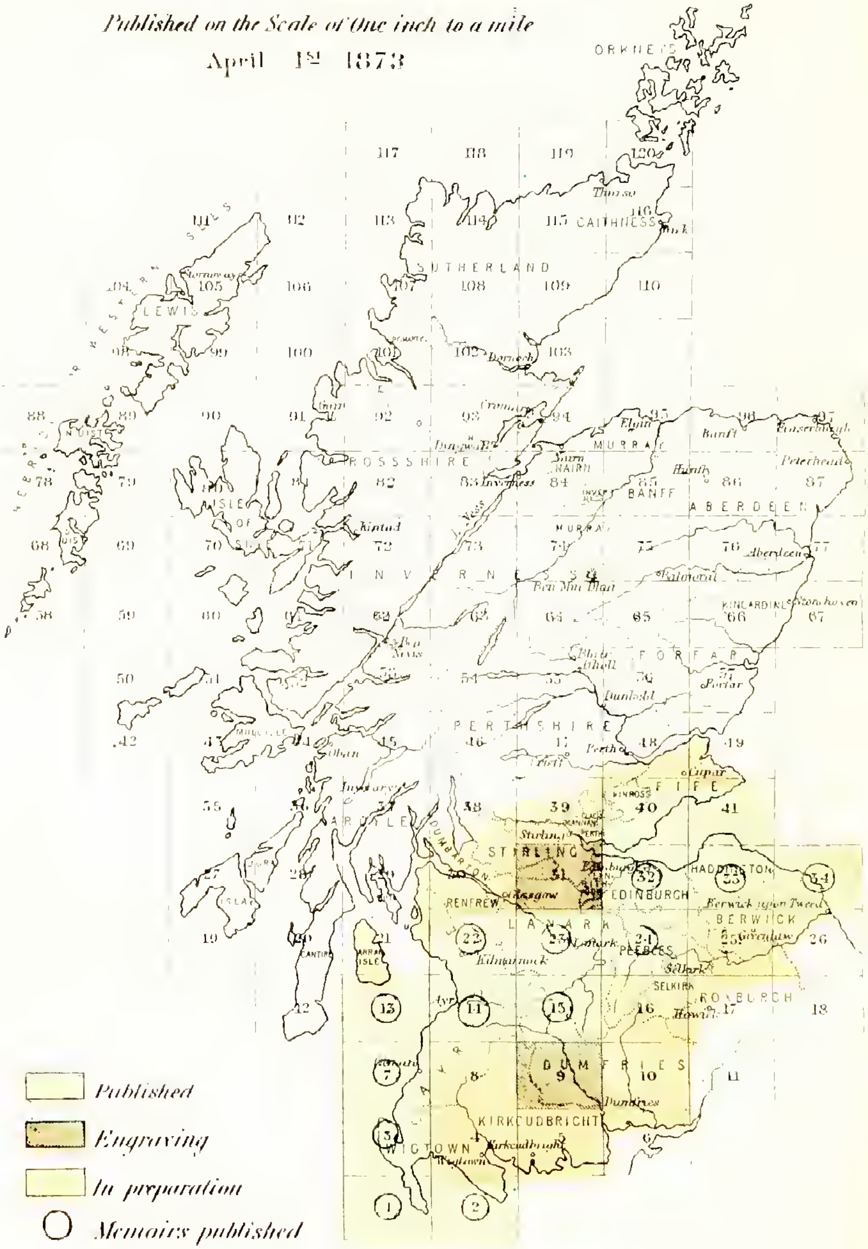
EDINBURGH:
PRINTED BY MURRAY AND GIBB,
FOR HER MAJESTY'S STATIONERY OFFICE.

1873.

Price Threepence.

INDEX
to the
GEOLOGICAL SURVEY MAP
of
SCOTLAND

Published on the Scale of One inch to a mile
April 1st 1873



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PREFACE.

Sheet No. 3 of the Geological Survey Map of Scotland, to which the present pamphlet is intended to form an accompanying Explanation, was surveyed during the General Directorate of the late Sir R. I. Murchison, and with my supervision and assistance, by Mr. D. R. Irvine, except a strip about half a mile broad at the extreme north-western edge of the Map bordering on Sheet 7, which was examined by Professor Ramsay.

Of the following Explanation, pars. 6–30 have been written by myself, the remainder by Mr. Irvine.

The list of fossils in the Appendix II. has been prepared by Mr. R. Etheridge, jun., by whom the specimens were determined.

Regarding the geology of this part of Scotland, a number of papers have been published chiefly by Mr. Carrick Moore, who, as far back as 1839, brought to the notice of geologists the occurrence of fossils in the rocks of Galloway. The following list comprises, I believe, all the special papers which treat of the area embraced in the present Map:—

1839. On the occurrence of Graptolites in the Slate of Galloway. By C. Lyell (*Proceedings Geol. Soc.* vol. iii. p. 28). [A brief notice of the discoveries by Mr. Carrick Moore of graptolites in the slaty rocks of Loch Ryan. No species are given.]

1840. On the Rocks which form the West Shore of the Bay of Loch Ryan in Wigtownshire, N.B. By John Carrick Moore (*Proc. Geol. Soc.* iii. 277).

[In this paper the author recognises the rocks as forming part of 'the great greywacke chain.' He notices the prevailing strike, the conglomerates, and the graptolites of these older rocks, also two of the 'trap-rocks' by which they are traversed. He brings to light the fact that rocks newer than the greywacke occur on the west side of Loch Ryan, identifying the red and white sandstones, etc. with the 'coal measures of Ayrshire,' and noting the occurrence in them of *Stigmaria* and *Calamites.* He shows that the breccia overlies these sandstones, but he assigns no geological horizon to it.]

1848. On some Fossiliferous Beds in the Silurian Rocks of Wigtownshire and Ayrshire. By J. Carrick Moore (*Quart. Journ. Geol. Soc.* v. 7).

[Gives a map, sections, and description of the western part of Wigtownshire from Corsewall Point to the Mull of Galloway. Notices the occurrence of graptolites at several points, of granite to the north of the Mull of Galloway, and of the coarse conglomerates near Corsewall Point. Reports the existence of fossiliferous Silurian limestones from the south of Ayrshire. In an appended note the late Mr. Salter describes the fossils from Wigtownshire and Ayrshire.]

1851. On the Silurian Rocks of the South of Scotland. By Sir R. I. Murchison (*Quart. Journ. Geol. Soc.* vii. 137).

[In one section of this paper, devoted to the 'schistose rocks ranging through Wigtownshire and Galloway to Kirkcudbright,' the author suggests that possibly these rocks may overlie the Ayrshire limestones—an idea which subsequent researches have not confirmed.]

1856. On the Silurian Rocks of Wigtownshire. By J. C. Moore (*Quart. Journ. Geol. Soc.* xii. 359).

[Gives the results of a careful examination of the geological structure of the western part of the county, and states that in the plication of the rocks the axes of the folds have been inclined to the north. Places the graptolitic shales under the coarse conglomerates of Corsewall, and suggests a possibility that the rocks of the Mull of Galloway are repetitions of those of Corsewall.]

I have here and there inserted a reference to the recent work of the Geological Survey in the Silurian uplands of the south of Scotland. That work has now extended over nearly the whole of these wide uplands, with the result of establishing the order of succession upon careful and minute mapping of the districts. For the first time the great mineral groups have now been recognised in their stratigraphical order, and traced across the country, parish by parish, from the headlands of Galloway to those of Berwickshire. The black shale group, for example, known as the Moffat shales, with the overlying and parallel zones, has in this patient way been tracked from district to district. It has thus been possible to make out the structure of this Silurian region—a task which has hitherto proved impossible from the want of correct details.

The general result of the work shows that the Silurian rocks of the south of Scotland belong for the most part to the Llandeilo formation. Their base is nowhere seen, for along the great axis which passes from Dumfries north-eastward across Eskdale, it is still rocks belonging to the same great series which rise to the surface. From that axial line, a general ascending series, as is well known, may be traced towards the north-western margin of the Silurian high grounds. Innumerable minor plications of the strata occur, together with several which cover a considerable breadth of country. It is in some of those broader folds that certain detached outliers of Caradoc age occur. One of these has been described in the Explanation to Sheet 15, as occurring among the Lead Hills. Others have since been traced both to the south-west and north-east. From the fact that these Caradoc patches do not always lie on the same zone of the Llandeilo series, but even cross from one zone to another, it is evident that in the south of Scotland there occurs an unconformability between the Caradoc and Llandeilo rocks—a new feature in the geology of Britain.

Another and still more violent unconformability must exist between the Upper and Lower Silurian rocks. This may be suspected from the comparatively untilted condition of the former at only a short distance from the crumpled beds of the latter, as at Lesmahagow and Muirkirk. On the southern headlands of Kirkcudbright also, Upper Silurian rocks appear but a short distance from the great Lower Silurian axis—a position only intelligible on the supposition of a great unconformable overlap of the later upon a very low part of the older series.

The details of this work will be given in subsequent Explanations. I will only add that it is mainly by the zeal and ability of my colleagues, Messrs. Peach, Jack, Horne, Skae, and Irvine, that the detailed structure of the Silurian uplands of the south of Scotland has at last been unravelled.

In Appendix III. there is added a List of Silurian fossils, the greater part of which were collected and named by the officers of the Geological Survey as far back as the years 1863–4. Owing to the necessity of proceeding with the mapping of the great coal-field tracts after the Silurian edges of that area had been traced, the further examination of that part of the Silurian region had to be delayed, and hence this list has hitherto remained unpublished. As it may be of service to geologists who take an interest in these rocks, it is now printed in anticipation of the fuller and more detailed lists which will be given in the Explanation to Sheet 8, where the geological structure of the districts will be described. From the list it will be observed that in the south-west of Ayrshire there occur representatives of Upper Silurian, Llandovery, Caradoc, and Llandeilo rocks.

ARCH. GEIKIE,
Director.

GEOLOGICAL SURVEY OFFICE,
EDINBURGH, *August* 1873.

EXPLANATION OF SHEET 3.

I. AREA EMBRACED IN THE MAP.

1. The area included in this Sheet amounts to 178 square miles, the whole of which lies in the county of Wigtown with the exception of a small portion at the north edge of the Map, towards the mouth of Loch Ryan, which comes into Ayrshire. Rather more than half of it belongs to that portion of Wigtownshire locally known as 'the Rinns,' stretching between the Irish Channel and the line of Loch Ryan and Bay of Luce. The remaining portion of the Map, consisting of the high ground to the north of Luce Bay and the east of Loch Ryan, forms part of the district called 'the Moors,' the greater portion of which comes into the neighbouring Sheet 4.

II. FORM OF THE GROUND.

2. The area represented in this Map is divided into three distinct forms of ground:—1st, The rough hilly ground of the Rinns; 2d, the heathy uplands of the Moors; and 3d, the flat plain or valley separating these two areas, and stretching between the hollow of Loch Ryan and that of Luce Bay. The eastern division is an undulating tableland, which towards its southern edge has an average height of about 400 feet above the level of the sea, but gradually slopes upwards to the northern edge of the Sheet, where it averages 700 feet in height. This area is nearly all moor and pasture land, the cultivated tracts being almost entirely confined to narrow strips along the courses of some of the streams. There is not much rock exposed in the upper half of this division, the greater part of the ground being covered with a coating of peat from one to ten feet in thickness, thus giving the surface a smooth, undulating aspect, which is wanting in the south half, the ground there being much more broken and rocky, with low but precipitous hills rising up here and there. The highest elevation in this district, and also in the whole Sheet, is the hill of Mid Moile, at the north edge of the Map, half way between Loch Ryan and the Main Water of Luce. It reaches a height of 844 feet above the sea level. The middle division is a low, flat plain, about four miles broad, lying between Loch Ryan and the Bay of Luce. It has an average height of from 70 to 100 feet above the level of the sea, with a gradual slope down to the beach at either end. This platform is cut through the centre by Piltanton Burn, which forms a broad alluvial flat at Genoch House. There are numerous hollows here and there over this area, most of which still contain deep lochs of different sizes, the largest being the White and Black Lochs of Castle Kennedy, each of which is fully a mile in length; and where lakes are now wanting, there are evident signs, such as the fragments of old beaches,

of their having once filled the depressions. Indeed, some of these dry hollows have been emptied by drainage within the memory of some of the older inhabitants of the district. The whole of this tract has long been under cultivation, with the exception of a strip of sand-hills along the shore of the Bay of Luce, only used as a rabbit warren. The remaining district is a continuation of the ground in Sheet 1 to the south, which forms the peninsula ending in the Mull of Galloway, though from Portpatrick northwards it is generally higher in level. The greater part of the surface has been brought under cultivation, the most important tracts still remaining in a state of nature being the Moors of Galdenoch and Larbrax, and the rocky hills of Cairn Pyot, Craigenlee, and Killantringan. The highest elevation in this district is Cairn Pyot Hill, 593 feet above the sea.

3. The coast-line along the whole extent of the western boundary of the Rinns presents a line of precipitous cliffs facing the Irish Channel. From the northern edge of the Map south to Portpatrick, these cliffs, though broken and steep, are not so high as they become farther to the south, where, between the bays of Portayew and Cairngarroch, they reach the height of 400 feet above the sea. Broken cliffs also, seldom 100 feet high, and usually much less, rise from either side of Loch Ryan for two miles south from its mouth. Along the rest of the coast-line of the Map, the ground slopes gradually down into the sea, forming for miles together flat sandy and muddy beaches, which are laid bare along the greater part of their extent for about half a mile at low water. On the west shore of Loch Ryan, at Kirkcolm, a spur of gravel runs into the loch for fully a mile, most of which is covered by high tides. One feature of the coast-line cannot fail to arrest the attention of the observer, viz. the constant relation of the indentations to the varying nature of the rocks. The headlands are found to consist usually of hard rocks, such as massive beds of greywacke, while the bays and creeks have been cut out of softer rocks, which in most cases are fissile shales.

4. There is only one main river-valley in this Map, that of the Water of Luce, which runs through the high ground forming the eastern division of the Sheet. Its general direction is from north-west to south-east, or at right angles to the line of strike of the greywacke rocks through which it cuts. The only other stream of any size is Piltanton Burn, which rises about three miles north-west of Stranraer, running south-east for the first half of its course, when it forms a boundary between a band of Permian and Carboniferous rocks and the Lower Silurian area. It then turns eastwards, and flowing in that direction with many windings, enters the Bay of Luce near the eastern edge of the Map.

III. FORMATIONS AND GROUPS OF ROCKS ENTERING INTO THE GEOLOGICAL STRUCTURE OF THE DISTRICT.

Aqueous or Sedimentary.

Recent.	Alluvium, Peat. Blown Sand. Raised Beaches.
Drift Series.	Sands and Gravels, and Stratified Clays. Boulder-Clay.
Permian.	Red Breccia.
Carboniferous.	Reddish Sandstones and Clays.
Lower Silurian (Llandeilo).	Greywacke, Shale, Conglomerate, etc.

Igneous and Metamorphic.

Of Miocene Age.	Basalt-rocks in dykes.
Associated with Lower Silurian Series.	Altered Strata, with distinct bedding, passing into crystalline amorphous masses. Felstone. Diorite.

IV. GEOLOGICAL STRUCTURE OF THE DISTRICT EMBRACED IN THE MAP.

5. The portion of Scotland shown on the present Map forms part of the extreme south-western end of that great range of Lower Silurian rocks which stretches from the Mull of Galloway to St. Abb's Head. The basement rocks belong, therefore, to the Lower Silurian series, and cover the whole of the surface, with the following exceptions:—1st, For about seven or eight miles on the west side of Loch Ryan a narrow strip of Carboniferous and Permian rocks occurs; 2d, Much of the surface is obscured with drift, more especially in the low grounds; and 3d, Along the margins of the larger streams, also along the sea coast at the head of Loch Ryan and of Luce Bay, considerable masses of alluvium or of blown sand obscure the solid rocks underneath; while throughout the whole of the district peat spreads sometimes over considerable areas, not merely on the sites of former lakes, but on the less steeply-sloping surface of the moors.

Lower Silurian.

6. With the exception of the small strip of Carboniferous and Permian rocks on the west coast of Loch Ryan, all the other solid aqueous strata belong to the Lower Silurian series. Magnificent sections of these strata are laid bare along the whole extent of coast-line washed by the Atlantic, and good exposures are also met with on the eastern shores of Loch Ryan and the western coast of Luce Bay. Others may be seen along the course of the Water of Luce and its numerous tributaries, and in the many streams that flow down the western slopes of the moory tracts stretching between Mid Moile and Cairnscarrow into Loch Ryan and Piltanton Burn.

A glance at the Map will show that, north-west of a line drawn from Morroch Bay by Garthland Mains and Dunragit Moor to Camrie Fell, the general dip of the strata is towards the south-east, the strike being, of course, north-east and south-west. There are frequent dips, however, in the opposite direction, showing that the strata are in some places rapidly folded. The persistent south-east dip is best seen along the sea coast, where the strata are most exposed. In the hilly districts east of Loch Ryan, the sections are less continuous, and a general south-east dip is by no means so apparent. It may be added that the angle of dip is seldom less than 50° or 60°.

South of the line just referred to, it will be observed that while the strike of the strata continues the same, the beds yet dip towards the north-west—that is, in precisely the opposite direction. This line then forms a synclinal axis. On the southern as well as on the northern side of the syncline, the strata are thrown into innumerable minor folds. The dips are frequently deceptive. There is reason to believe that the strata are, in many places, folded back upon each other in a series of rapid plications, the tops of which have been removed by denudation. Thus we have the appearance of a vast thickness of strata dipping, often for long distances, in one determinate direction. The same beds, in fact, again and again appear in the section; and what seem to be overlying, are, in truth, frequently underlying strata. Examples of this structure may be seen abundantly along the coast sections, as between Grennan Point and Saltpans, and between Broadsea Bay and the Lighthouse.

7. From the fossil evidence obtained from these rocks, it may be inferred that they are all referable to the Llandeilo series. Their base is not seen, nor have they been observed to be covered here by rocks containing Caradoc fossils. Evidently they form a continuation of the Llandeilo rocks, which have been already described as they occur to the north-east in Sheet 15. From the labours of the Geological Survey over the Silurian region between the present district and Clydesdale, it has been found possible to divide the older rocks of these uplands into several groups, which, though on the whole not well discriminated by fossils, have, nevertheless, tolerably persistent lithological characters, by which they have been traced across the kingdom. Several of these groups are clearly recognisable in the present area, though with some differences from the aspect under which they were first studied and named in the central district of Nithsdale and Clydesdale. In the order of superposition they are as follow :—

(6.) Upper or Lead Hill Black Shale Group,	(Group G of Sheet 15).
(5.) Lowther Group,	,, F ,, ,,
(4.) Dalveen Group,	,, D ,, ,,
(3.) Queensberry Grit Group,	,, A ,, ,,
(2.) Lower or Moffat Black Shale Group.	
(1.) Ardwell Group.	

8. Had the rocks been folded into a simple synclinal trough, those on the one side should have been approximately a mere repetition of those on the other. Owing, however, to the complicated foldings just referred to, some of the groups are made to cover a much larger space, or to occur a greater number of times. For example, on the north side of the syncline, the group No. 4 is so crumpled back upon itself that it covers by far the largest part of the area up to the edge of the Map. On the south side, on the other hand, that group, being less crumpled, is made to occupy a much narrower breadth, while the lower groups are repeated over a considerable space.

9. (1.) **Ardwell Group.**—Under this name is included a series of hard, well-bedded greywackes and grits, with bands of hard shale or slate. These rocks have a prevailing reddish or brownish hue, especially on weathered surfaces. The shales are sometimes grey, often red or purple, and frequently show cleavage. No fossils were noted in them in this district, though obscure markings occur here and there like the *Protovirgularia*. The same rocks rise from under the Moffat shale group all the way across the country through Kirkcudbright, Dumfriesshire, and Selkirkshire, into Roxburghshire. In the present district, they occupy a band nearly three miles broad, extending from near Grennan Point, at the southern edge of the Map, northwards by Ardwell Point, where they are well developed, to near Slunkrainy. The general inclination of the beds throughout that band is south-eastwards. In spite of this apparent dip, however, there can be little doubt that on the whole the rocks are arranged in an anticlinal fold, and that many of the dips are really reversed. This may actually be seen to be the case at several parts of the coast section. On the band at Saltpans, for example, a well-marked anticlinal axis is shown, and yet the prevalent south-easterly dip is not changed by it. In the Map to the south of the present (Sheet 1), the same rocks rise up again from under the lower

black shale group, and form the headland of the Mull of Galloway. The band of them in the present Map lies thus to the north of the normal line of strike by which these rocks are carried from the Mull of Galloway across to Tweeddale. It is brought up along one of the lines of axis already referred to. Much farther to the north-east, in the high grounds of Hartfell, Loch Skene, and the head of Yarrow, other axes occur, sometimes bringing up parts of the Ardwell beds, as is done so conspicuously on the Wigtownshire coast-line. The mapping out of these folds is of the utmost importance in enabling us satisfactorily to reduce the apparently enormous thickness of the Lower Silurian rocks of the south of Scotland.[1]

10. (2.) **Lower or Moffat Shale Group.**—This name is applied to a series of flaggy greywackes and grey shales, of which the distinguishing characteristic is the occurrence among them of several bands of black carbonaceous shale. These dark shales have long been known as occurring in many places among the southern counties of Scotland. In the neighbourhood of Moffat they are particularly well developed, and hence they have been termed the Moffat Shales. They have now been traced by the Geological Survey from near Melrose across the whole breadth of the kingdom to the far shores of Wigtownshire—a distance of more than 100 miles. Throughout that long distance, they present a remarkable similarity of character. Sometimes three bands can be made out; in other places the bands come together so as to form a thick shale zone. Intercalated with them are green and red shales, while there frequently occurs also a hard argillaceous bed, paler in colour than the grey shales, and not laminated.[2] The black shales are usually much broken and twisted. They likewise abound in iron pyrites with veins of quartz. They have yielded graptolites. (See Appendix.)

11. As the coast sections display the succession of beds in this important group better than any of the streams of the interior, it may be of service to describe one of these, viz. that which is exposed at Drumbreddan Bay. The strata have a general south-easterly dip, resting on the Ardwell Group at the one end of the section, and passing under the Queensberry Grit Group at the other. The following section shows the succession from the latter group down to the former:—

Grey fissile shales. Some beds are very sandy, and abounding in grey, hard, sandy, calcareous nodules and lenticular beds. Part of the bend is obscured by gravel and boulders; but these shales probably cover a space of about 140 yards. As they are nearly vertical, their thickness may be not far short of 400 feet.

Black shale bands, 12 to 18 feet thick, embedded in the lower part of the grey shales, which contain numerous thin lenticular partings of similar black shale both above and below the main bands.

Grey shale, finely laminated, 3 or 4 feet.

Grey flagstones, flaggy greywacke, and grit, in beds of various thickness up to 3 or 4 feet, with abundant partings of grey shale. This flaggy series covers a space of about 100 yards, and probably exceeds 250 feet in thickness. The beach is now obscured by red boulder-clay, gravel, and sand for a space of 86 yards. This blank probably represents the place of another zone of shales, for beyond the interruption the next strata visible are

Black shales, so much jumbled and jointed that their true thickness cannot be satisfactorily determined. In the upper part of the visible section they contain several thin bands of the soft grey and yellow clay above noticed, together with hard, thin, black, flinty bands. The crumpling and fracture of these strata are such, that probably the same layers are repeated again and again. At one place the black shales appear to rest directly upon hard, grey, flaggy shales, at another, upon one of the clay-beds. This shale zone is succeeded immediately by

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[1] The working out of the north-eastern area is at present in the hands of Mr. B. N. Peach.

[2] This clay-bed has been used by Mr. B. N. Peach in the survey of the Selkirkshire and Roxburghshire area as an index, since it always occurs there immediately below the lowest band of black shale, where it reminds one of the fire-clay below a coal-seam.

Well-bedded greywacke and grit, in beds varying up to 3 or 4 feet thick, with occasional shaly partings and one or two thicker bands of grey flaggy shale. This zone has a total breadth upon the coast-line of about 140 yards, and is probably not much less than 400 feet thick. The greywacke beds, though still parted with thin shale, are more massive at the base, where they rest directly upon

Black shales. This zone shows admirably all the characteristic features of the black shale of the Silurian rocks in the south of Scotland. The strata are so intensely plicated as to defy any attempt to ascertain satisfactorily their true thickness. They contain some striking examples of the intercalation of those pale grey, greenish, or yellow clays like the fire-clays of the coal-measures. The contrast of colour between these beds and the black shales lends additional aid in following out the beautiful curvatures and faults exposed upon the beach. It is possible that, in spite of the frequent alternation of the two kinds of rock, there may be in reality only one band of the pale clay, its repetition being due to the innumerable foldings which the strata here have undergone. Another conspicuous feature of the black shales is the occurrence in them of calcareous nodules and lenticular bands like the cement stones of the Lower Carboniferous rocks, while their resemblance to these younger palæozoic strata is further borne out by the appearance in them of ribs and nodules of a coarse pyritous clay-ironstone. Although this strip of black shale covers the greater part of the little inlet north of Drumbreddan Bay, it perhaps does not amount to as much as 40 or 50 feet in actual thickness. At the base lies a series of

Grey and reddish shales, and clays with calcareous bands and nodules, and enclosed bands of black shale, perhaps about 50 feet thick. At the base they are hard and flaggy, and rest immediately upon a vast series of grey and reddish greywacke flags forming the Ardwell Group (par. 9).

From this section it would appear that the Moffat Shale Group in this part of the country has a thickness of somewhere about 1000 feet, considerably more than half of which consists of flaggy greywacke beds.

12. To the south of Drumbreddan Bay lies a great synclinal trough of the Queensberry Grits (Group 3), on the farther side of which, at Clanyard Bay, in Sheet 1, the Moffat shales rise in full force again, to be succeeded by the Ardwell beds of the Mull of Galloway. On the north side of Drumbreddan, the underlying Ardwell series, after occupying the coast sections from Grennan Point to near Slunkrainy, allows the black shale group once more to appear. At that part of the coast-line, a thick series of shales and hard greywacke bands occurs containing several bands of black shale. The rocks are here much twisted and broken, besides being invaded by intrusive masses of felstone, but graptolites have been obtained from the dark shales.

The two lines of outcrop now described, stretching north-eastward, the one from Drumbreddan Bay, the other from Slunkrainy, are the only places in the present Map where this lower series of black shales can be seen. Their existence is due to the rise of the Ardwell axis, from which they dip away on either side. To the north they are succeeded by higher members of the Llandeilo series, which, though thrown into innumerable folds, never allow this lower series of shales to rise again to the surface.

13. (3.) **Queensberry Grit Group.**—The general characters of this well-marked and persistent band are given in the Explanation of Sheet 15, where the rocks are described as occurring in great force in Queensberry

Hill, and stretching thence north-east and south-west in the general line of strike of these rocks. They retain the same features even to the extreme south-western coast-line of the country, consisting of thick-bedded greywacke and grit in massive courses, with occasional bands of grey and greenish shale. The massiveness of the beds in this arenaceous series, the regularity of their bedding and jointing, whence they can be readily used for lintels and flags, and the frequent coarseness of their texture, passing at times into coarse conglomerate, distinguish the Queensberry group from all the others. In the present district they have not yet yielded any fossils.

14. This group crosses Wigtownshire in three parallel bands, which are merely repetitions of each other caused by the plication already referred to. The first of these lies to the south of Drumbreddan Bay, and comes only partially into this Map on the east coast, south from Chapel Rossan Bay. But in the Map to the south (Sheet 1) it covers a considerable space, since it occupies the synclinal trough between the outcrop of the Lower Black Shales in Drumbreddan and that in Clanyard Bay. To the north-west of the Black Shales of Slunkrainy, an admirable exposure of the Queensberry grits may be seen on the cliffs of Money Head. The general dip is north-westerly at high angles. There appear to be comparatively few curvatures in this part of the coast section, consequently the Queensberry group is made to cover a smaller breadth upon the Map than it usually does. Some of the strata are quite pebbly in texture, but no actual conglomerate was observed in the course of the Survey,—a fact which is deserving of remark, since bands of course conglomerate occur in the other two bands above referred to. A gradual increase of the flaggy character may be traced as we round Money Head towards Scarty Head. The strata of greywacke become thinner and more divided by partings of shale until the group passes insensibly into the next in order, that which has been named the Dalveen Group (No. 4).

15. When this change takes place, the coast-line northwards continues to be occupied by higher members of the series. The synclinal trough, as already mentioned, runs north-eastward from Morroch Bay. But, while on the south side of that trough the whole breadth of the different groups above the Queensberry beds is less than three miles, on the north side these beds are separated from the centre of the trough by a space of fully twelve miles—a difference due to the much greater plication and repetition of the rocks on the latter than on the former side. After passing over these twelve miles, which are covered almost entirely by endless folds of the group next in order, we again come upon the characteristic thick-bedded greywackes and grits of the Queensberry series. These begin on the coast between the Genoch Rocks and the Ox Rocks, where the overlying flaggy and shaly group passes down into them. Several faults occur on the shore hereabouts, one of the most conspicuous being marked upon the Map. The actual throw of these dislocations is probably insignificant. They are fractures rather than faults, occurring among highly-inclined or even vertical beds; and strata having the same characters, and belonging to the same group, are found on both sides of them. There is, therefore, no sensible interruption here of the usual order of succession among the strata. The Queensberry group gradually passes out from under the overlying beds, and soon assumes its characteristic features. But it acquires also a very remarkable conglomeratic aspect. Beds of conglomerate occur in abundance, and so coarse as to deserve the name of boulder-beds. Many of the stones are two or three feet in diameter. As a rule, they are well rounded. In a hundred stones,

broken at random from the thick bed of conglomerate at the Corsewall Lighthouse, the following proportions were noted in their composition:—

Granite, chiefly pink	30 per cent.
Diorite	24 ,,
Quartziferous porphyry	15 ,,
Felstone	10 ,,
Lydian Stone	7 ,,
Greywacke, usually altered	8 ,,
Quartzite	4 ,,
Quartz	2 ,,
	100

These massive conglomerates with bands of greywacke form all the northern end of this promontory of Wigtownshire.

16. (4.) **Dalveen Group.**—Under this name are here included all the strata which intervene between the Queensberry group and the Lowther Shales (No. 5). The lower part of the series is sometimes remarkably shaly, and this cannot be better seen than where it begins to overlie the Queensberry group to the south of Corsewall Lighthouse. But thick masses of jointed greywacke likewise occur. The whole group, as developed in this part of the country, may be described as consisting of well-bedded, jointed greywacke, with partings and frequent thick zones of grey and blue shale. In some of the shale bands fossils occur. To this group belong the so-called "slates" of Cairn Ryan, from which, as well as from other similar bands, numerous graptolites have been obtained (see Appendix). But the group appears to be further characterized by the occurrence in it of a thin band of black shale containing graptolites. This seam occurs twice along the western coast section. On the south side of the syncline, it crops out in the cliff at Portayew among the bands of greywacke and shale; on the north side, it has been noticed on the shore of Knock Bay, embedded among similar rocks. It has the usual characters of the black shales already described, the crumpling and fracture of the layer being particularly well shown at Portayew. The evidence seems to be, on the whole, in favour of classing this black shale with the Dalveen group, although it may possibly in the end be shown to be really the upper black shale of Group 6, as explained in par. 22.

17. The Dalveen group is found on both sides of the synclinal trough. On the south side it may be regarded as stretching from Scarty Head to beyond Knockienausk Head—a distance of rather over two miles. As the strata throughout this distance are for the most part thrown into high angles of dip, or quite on end, the thickness might be supposed to be enormous. On examination, however, it is found that here as elsewhere the rocks have been folded again and again back upon themselves, so that the actual thickness of rock is probably not a third of what it seems at first to be. Some magnificent curvatures of the strata are to be seen on the face of the huge cliffs by which Cairnmon Fell shoots out of the sea. On the north side of the syncline, the Dalveen beds, as already remarked, cover a much greater space. They begin where the Queensberry group ends off, near the Ox Rocks, and their southern limit seems to stretch beyond Portpatrick, though, owing to the metamorphism of that area, described in par. 23–27, its southern boundary there cannot be very accurately defined. Thus, over a breadth of fully eleven miles, the Dalveen series passes across this peninsula of the county. Such a breadth indicates the extreme plication of the rocks, for there is no reason to suppose that they are thicker on the one side of the basin than on the other. In fact, they are repeated upon themselves times without number,

and this even though a general southerly dip is preserved, for the axes of the folds are not vertical, but rise towards the north-west. This can be seen along many parts of the fine coast sections, as, for example, to the south of Portobello. Amid such intense contortion, one might naturally expect to find that sometimes along the anticlinal folds some parts of the underlying group would be brought up, while, in the synclinal folds, portions of the overlying series would be caught and retained. It is possible that some of the greywacke zones may be parts of the Queensberry series, but this is not certain. More satisfactory are the proofs that here and there, in the deeper troughs, portions of the overlying shale series have been folded. Two or three conspicuous examples occur of this probable structure, one a little north of Broadsea Bay, where, for a space of about half a mile, the coast is occupied by a thick series of grey and olive shales, precisely similar to those of the Lowther series. Some beautiful examples of foldings with reversed dips may be seen among these shales. Another instance occurs farther north, between Slouchnawen Bay and Strool Bay, where similar shales and flagstone, sometimes wonderfully twisted and curved, cover the shore for a space of about three-quarters of a mile. These zones are thicker than any shale bands in the Dalveen group, and have so exactly the character of the next group that they may, without much hesitation, be referred to it.

18. It is this Dalveen group of greywacke and shale which, stretching towards the north-east, covers most of the rest of the Silurian area of the Map. The same characters, which are so well seen on the western coast-line, may be traced inland across the moors, though the continuous sections there are comparatively few. The harder or greywacke beds form the knobs of rock at the surface, while the softer or shales are usually more or less buried under turf or drift. About Auchmantle and to the north of Gleniron Fell there is a decided preponderance of thick-bedded gritty greywackes, with only occasional bands of grey shale. About Crailloch, and crossing the tract of low drift-covered ground about Stranraer, in the hilly ground between Inch and New Luce, the dips are both to the south-east and north-west, showing considerable foldings in the beds. The shales and shaly greywacke beds are often a good deal hardened in this group. They likewise show very twisted and contorted bedding. Near the metamorphic area, at the south edge of the group, they have suffered a slight metamorphism, the shales being very hard and splintery, and often baked into a solid mass. Here the cleavage lines, which are more or less discernible in the shaly beds all along the coast-line, become much more distinct. A good example is seen at the headland of Catebraid, a little north from Portpatrick, where some bands of shale are traversed by cleavage planes, cutting through the bedding, and dipping with it, but at a lower angle. At the north end, near Corsewall, the alteration of the shales has been considerable; they have there been converted into a shattery compact rock, resembling a coarse kind of porcellanite. The greywacke and gritty beds have likewise been hardened and otherwise slightly altered towards the south. Much broken by joints, they all contain numerous veins of quartz and sometimes of calcite—the latter being frequently found, with hæmatite, and now and then chlorite, forming coatings along the sides of the larger joints. Diffused oxide of iron occasionally stains the rocks of a red and purplish colour. The bands of black shale are very much crumpled and broken. In a series of grey shales, with interbedded greywackes, to the north of New Luce, some thin veins of lead ore occur, which have been worked at Knockibae.

19. (5.) **Lowther Group.**—Next in order comes a series of shales and

flags, with greywacke bands, answering in general character to the corresponding series in the Lead Hills region, to which the name of the Lowther Group has been given by the Geological Survey. In that region the group, as its name implies, consists in great part of shale. Traced south-westward, however, the shale gives place more and more to greywacke flagstones and grits with shale bands and partings. This character is more especially marked along the north side of the syncline of Black Shale described in par. 22, where it would appear that sandy deposits were laid down as a long bank during the time that the more muddy material of the shales was accumulating to the north-east and south. Hence on the south side of the syncline the group is more decidedly shaly than on the north side, as may be seen by comparing the coast sections to the south and north of Morroch Bay, or the ground to the south-east of Camrie Fell, with the rough craggy area to the north-west of that hill. From the boundary of the Dalveen beds northwards, close up to the synclinal axis, this group stretches from the west coast across the Map, by the head of the Bay of Luce, to Glenluce, whence it passes into the adjoining Sheet. Most of this area, however, is covered with drift and sand, the only good section of the rocks being along the shore of the Irish Channel. The strata form there a line of cliffs from 100 to 300 feet in height, between Morroch Bay and Knockienausk Head, and consist of masses of grey and greenish shale, often twisted and broken, sometimes very fissile and micaceous, and of grey flags, with interbedded hard, blue, fine-grained greywackes, much broken with joints. Veins of quartz and calcite run more or less through all the beds, and dykes of igneous rock are likewise abundant along the face of the cliffs. The flags are most fully developed at the top of the series, and have been quarried for roofing and flooring purposes. Eastwards, also, at the edge of the Sheet, in the Water of Luce, the grey flaggy shales are still the most prominent beds. Along the coast, north to Port of Spittal Bay, the strata of this group dip to the north-west, generally at a high angle, and, with the exception of a south-east dip which comes on for a short distance in Eldrig Burn, two miles inland, this is the constant direction across the Sheet. Though the synclinal axis appears to begin in Port of Spittal Bay, on each side of which the beds have a general dip towards each other, yet, if we may be guided by the structure of the wide region to the north-east, it is more probable that the black shale group, which comes on in Morroch Bay, some hundred yards to the north, marks the true line of the fold. Towards the eastern margin of the Map, the dips of the rocks show that the latter group really does lie in the line of the synclinal axis, and therefore overlies the shale and flagstone group just described, as, in the typical region of the Lead Hills, the black shale group overlies the Lowther group. The beds between the black shales and the apparent axis in Port of Spittal Bay are inclined at a very high angle, so that a small amount of reversed folding would suffice to give them a south-east dip.

20. From Portpatrick to Piltanton Burn, the area occupied by the flags and shales, which are here classed with the Lowther group, has been metamorphosed very considerably, and will be separately described further on. The position and extent of this area of metamorphism are shown upon the Map. As already mentioned, the alteration of the beds obscures the boundary between this group and that below. No good section of these rocks can be obtained inland along the northern side of the trough; but where they are exposed on Glenwhan Moor, and still more admirably on the Fells of Craig and Gleniron, they dip at high angles towards the south-east. Both the greywackes and shales have

been considerably hardened, and show the usual reticulated veins of quartz, with sporadic patches of still greater alteration. Faint cleavage appears here and there among them. Some of the greywackes pass here into coarse grits.

21. (6.) **Upper Black Shale Group.**—Though this series of strata has not yet been traced by the Geological Survey completely across the wild and rugged tracts of Galloway, between the valley of the Ken and the Wigtownshire Moors, there is every probability that the bands of black shale, which in the present Map lie along the synclinal trough, are the same as those of the Lead Hills. From the latter region they have been followed in two parallel bands south-westward up to the base of the great mountainous range of the Kells, and it is in continuation of the same line of strike that the black shales of the present Map reappear, and run from the Water of Luce south-westward to the Irish Channel. Judging, therefore, from the general parallelism of the zones, we are probably justified in at least provisionally placing these Wigtownshire beds on the same horizon with those to the north-east. Two bands of this upper shale group, each lying in a synclinal trough, cross the area of the Map. One of these crosses from Morroch Bay to Camrie Fell, and thence is prolonged into Sheet 4. The other appears to the south-west of Stranraer, and crosses the moors to the north-east, where it is well seen in the bed of the Water of Luce below Cairnarzean. If the bands of black shale alluded to in par. 16 as occurring in the Dalveen group should in the end be found to form part of the present group, the number of lines of outcrop will be increased. The difficulty of settling this point arises chiefly from the change (already mentioned, par. 20) of the Lowther shales into a more flaggy series that insensibly passes down into, and cannot in many places be satisfactorily discriminated from, the underlying Dalveen beds.

22. By far the best section of these black shales in this region, and, indeed, one of the best anywhere to be seen in the country, is that of Morroch Bay, about a mile and a half to the south-east of Portpatrick. As already explained (par. 6), they lie here in a synclinal trough, so that those in the northern half of the Bay are brought up again along the southern half. As nothing is found overlying them here in the centre, it is neither possible to ascertain their true thickness nor the character of the strata which come above them next in order. Arranged in descending sequence, they appear to be made up of the following zones:

c. Thick mass of black shales, with lenticular nodules and seams of coarse clay-ironstone, nodular layers of greywacke, and pyritous kernels (sometimes five or six pounds in weight) and partings which decompose. These shales have the usual fissile character, with hard flinty 'ribs' interstratified with the more shaly parts. They show much crumpling and fracture, besides being invaded, especially on the cliffs, by intrusive masses and veins of felstone. (See pars. 28–30.) Owing to these features, their thickness cannot be satisfactorily ascertained; for in spite of the space which the strata are made to cover, they may in reality be no more than fifty feet thick. For the graptolites of these shales, see Appendix.

b. Shales and flagstones. On the north side of the Bay these strata are of a general greenish grey colour, sometimes yellow, and occasionally purple. On the south side they become in parts bright red. The shales have a general fissile character, but become in some places hard and flinty, and intercalated with thin flagstones, bands of greywacke, and occasional lenticular seams of black shale. This zone may perhaps be about the same thickness as the black shales above it.

a. Hard lenticular and sometimes thick-bedded jointed greywacke, with numerous remarkable included masses of black shale of

> the usual characters. In some parts the greywacke looks like an intrusive rock which has been injected in veins through the shales, as may be well seen at the north end of the Bay. This curious zone may be taken to be about thirty or forty feet thick. It passes down into the hard greywacke flagstones and shales which represent the Lowther group, and in the upper part of which, at the north end of Morroch Bay, thin seams of black shale are intercalated.

In continuation of the Morroch Bay band the same shales may be seen occupying the centre of the syncline on the Water of Luce, between the old abbey of Glenluce and Gabsnout. As expressed upon the Map, they cover a larger space here than at Morroch Bay, seeing that the synclinal trough widens. The hill called Camrie Fell may be regarded as lying exactly in the trough. On its north side the shales may be seen resting upon the hardened flagstones, greywackes, and shales of the Lowther group of Gleniron Moor and plunging south-eastward. On its south side, again, the same shales can be traced dipping to the north-west. Camrie Fell itself appears to consist partly of crumpled black shale and partly of a small portion of the hard greywacke beds which, farther to the north-east, are found to overlie the upper black shale group.

As already mentioned, another band of black shale, which appears from the evidence obtained up to the present time to be in all probability a repetition of the Morroch Bay band, occurs at Crailloch Burn, a little to the south-east of Stranraer, and again where the rocks of the turf-covered moors have been deeply trenched by the Water of Luce below Cairnarzean. At the former locality the black shales have been thrown into several folds, and show the associated red and greenish shales as at Morroch Bay. In several of the synclinal troughs they are overlaid by a coarse gritty greywacke which recalls some portions of the Caradoc series of Kirkcudbrightshire and Nithsdale (Sheets 9 and 15). In the line of strike of the Crailloch Burn black shale band, a thick set of grey shaly beds and flagstones occurs upon the shore at Killantringan Bay. It is suggested that these may be a syncline of Lowther beds in which, were it a little wider, the Crailloch band should be found. That band, however, appears to 'nose out' before it reaches the shore, unless indeed we try to connect it with the black shale seen among the greywacke and flagstone of Knock Bay, which has already been provisionally classed with the Dalveen group (par. 16).

Metamorphism of Silurian Rocks.

23. Throughout the Lower Silurian tracts of the south of Scotland there occur, often at wide intervals, scattered areas over which the original greywacke and shale beds have undergone alteration, even to the total obliteration of the granular sedimentary character and the stratified arrangement, and to the conversion of the rocks into more or less crystalline amorphous masses, like those which are ordinarily regarded as igneous rocks. In some cases this metamorphism is associated with the appearance of a central nucleus of granite round which the Silurian rocks assume a schistose texture, as in the high grounds of Kirkcudbright and the north-west of Dumfriesshire. In other cases no granite appears, but the Silurian strata are found to pass into rocks which possess most of the ordinary characters of porphyrites, felstones, diorites, or other crystalline intrusive masses. This may be seen near Sanquhar (Sheet 15), and also between Girvan and Ballantrae (Sheet 7).

24. In the present Sheet, besides numerous smaller patches where the

rocks have been considerably hardened, a detached and limited area of metamorphism occurs, presenting features somewhat different from those of the two kinds of alteration just referred to. This area, as shown upon the Map, lies round the village of Portpatrick, extending along the coast-line from Morroch Bay to near Catebraid, and inland for two or three miles. It will be seen that there is no granite nucleus, and that no great mass of any intrusive rock occurs either in the centre or at any part of the metamorphosed area. Throughout this area the rocks, which farther to the north-east are still the ordinary greywackes and shales of the district, have been considerably altered. Their granular character has not been wholly effaced, but in many places an incipient crystallization may be traced, as if it were the remains of an arrested metamorphism of the Sanquhar or South Ayrshire type. Single specimens, or even detached cliffs of these rocks, are sometimes exceedingly puzzling, and not until a considerable part of their extent has been gone over does their true character become evident. They have been largely quarried on the coast at Portpatrick, especially to the south of the village, where the quarries lay open many excellent sections. The strata as there exposed are nearly vertical, and strike towards the north-east, sometimes hanging slightly to north-west, at other points to south-east. Though the stratification remains distinct, it has been much disturbed in some parts into minor folds.

25. The whole of these rocks have been greatly hardened. Where the metamorphism has been most developed, it shows itself in the greywacke by a partial obliteration of the granular texture and the appearance of an indistinctly crystalline texture, through which may be traced here and there striated plagioclase crystals and cubes of pyrite. Examined with the microscope, these more altered portions clearly show, what is sometimes tolerably distinct even to the naked eye, that the character and extent of the metamorphism have been largely determined by the original composition of the rock. The quartz grains form a minority of the sand-particles out of which the greywacke was made,—sometimes, indeed, almost disappear. These grains have suffered little or no change. They remain sharp and distinct as they originally were. It is the dark argillaceous base or matrix in which they lie which has undergone metamorphism. Hence, where a coarse quartzose grit occurs, it is observed to have suffered little change. Where, on the other hand, the quartz-sand has been small in quantity, and the rock has probably been a fine sandy silt or muddy sand, the metamorphism reaches its maximum. Yet the shale bands seem on the whole to have undergone less alteration than the greywacke. They are dark in colour and much hardened, but not porcelainized. Where most changed they cease to be fissile, and break with a splintery sub-conchoidal fracture. Here and there among them a rude cleavage is developed. Where they are interbedded in partings or other bands with the greywacke, the two rocks, instead of being as usual easily separable, are, as it were, welded into each other. It may be noticed also that small patches of the same material as the shale, either rolled fragments of some previously consolidated shales, or what were originally mere pellets of clay, like the 'clay-galls' in sandstone, occur both in the metamorphosed and ordinary greywacke.

26. Besides being hardened and partially crystalline, the strata are so shattered by innumerable joints as to present on a weathered face an angular rugged surface. Along these joints run veinings usually of calcite or quartz, sometimes of chlorite or barytes. They likewise show occasional veins or dykes of intrusive rock, some of which have been laid open in the cutting of the railway. One of these, coinciding nearly, if

not quite, with the line of bedding, shows much decayed hornblende, with a little mica and granules of quartz, in a basis of apparently plagioclase felspar. To such a rock the name of diorite is perhaps most appropriate. But the same rock is found not many yards distant to be exceedingly compact, and wearing much of the general aspect of the most highly altered parts of the greywacke.

27. Towards the north the metamorphism may be traced gradually passing away into the ordinary character of the rocks. On the southern margin the metamorphic area is more sharply defined by the band of black shale stretching inland from Morroch Bay. This thick band, which occupies the hollow of that bay, and indeed is the cause of its excavation between the two masses of hard greywacke which form its headlands, shows how rapidly the metamorphism disappears when the more alterable greywacke is replaced by shale. At the north end of the bay, next to the altered greywacke, the shales are black, and though much hardened, twisted, and broken, yet continue to show abundant graptolites. Farther south they appear as red and greenish bands, much less hardened and dislocated, while at the southern headland ordinary unaltered greywacke succeeds them.

Igneous Rocks in Silurian Series.

28. As shown upon the Map, the Silurian strata are traversed by numerous veins or dykes of intrusive rocks. As a rule, these intrusive masses run with the general strike of the district, that is, from south-west to north-east. Their date cannot be fixed from any evidence to be obtained in the district; but, like the other abundant dykes of similar character among the Silurian rocks of the south of Scotland, they are probably to be placed between the deposition of the Upper Silurian and Upper Old Red Sandstone rocks. The only exceptious to this probable date are presented by the dykes of basalt-rock, some of which are here found penetrating the Permian strata, and which from other evidence are assigned to as late a time as the Miocene Period.

29. Of the older or palæozoic series of dykes several petrographical varieties may be distinguished. The majority belong to the rock named *Felstone*, consisting of a white, grey, pink, or reddish orthoclase base with sometimes a little hornblende, or talc, or quartz intermingled. The base is usually compact crypto-crystalline, but sometimes assumes a finely crystalline character. A second variety of rock contains, in addition to the same kind of base, a much greater quantity of hornblende, as near Craigoch, two miles south-east from Portpatrick. These rocks are syenites, according to the German nomenclature. It often happens that part of the hornblende has been replaced by talc, as in the dyke near Little Float, four miles south-west from Stoneykirk, though this replacement does not seem to have been carried so far in this district as in that represented upon Sheet 2. (See the Explanation of that Sheet, par. 10.) A third variety is made up of a felspar base, very like that of the two previous varieties, in which, under the microscope, no trace of striæ can be seen, bnt through which are scattered, more or less abundantly, well-marked crystals of a striated felspar. They appear to consist of a finely crystalline orthoclase base, and to be porphyritic with crystals of plagioclase. A good illustration of this character is seen at Cairngarroch Bay, where also hornblende and black mica make their appearance. A fourth variety has the felspar of the base distinctly striated, and sometimes becomes porphyritic from the separation of large crystals of the same felspar—hornblende, talc, or mica being frequently superadded. Such

rocks are probably best classed with the *diorites*. Examples may be seen at Morroch Bay and Cairngarroch Bay. It should be added that pyrite occurs in all these rocks,—sometimes, indeed, forming a considerable proportion of the mass.

30. The mode of occurrence of these various intrusive rocks can best be understood by a reference to the Map, where the abundant dykes and veins along some parts of the coast sections are well exhibited. It has often been remarked, in the course of the work of the Geological Survey among the Silurian rocks, that these intrusive masses are apt to occur in segregated clusters of dykes and veins, with intermediate spaces, sometimes of wide extent, wholly or nearly free from them. The present Map furnishes additional examples of this fact. It may be observed also that the dykes and veins are frequently crowded together among the shaly or thin-bedded rocks, while in the thicker greywacke masses they are comparatively scarce. A curious feature was noticed at Portayew, where the band of black shale is traversed by a mass of pink and yellow felstone. The latter rock sends into the shale veins and threads, which, as well as the outer parts of the main mass in contact with the carbonaceous shale, are dull, pale, and earthy, strongly recalling the appearances presented by the 'white rock' in the coal-fields, where an ordinary dark pyroxenic mass has been injected among coals or bituminous shales.

Carboniferous.

31. This formation is represented in the present Sheet by a band, a few hundred yards wide, of grey, reddish, and mottled sandstones, and purplish clays, which extends for five or six miles on the west side of Loch Ryan, between the Silurian and Permian rocks. Few exposures of the rock can be seen, the surface being mostly covered with drift. A small outlier of sandstone is shown in a stream a quarter of a mile north of the main boundary line. These rocks have yielded a few fossils and plants of common carboniferous species. (See Appendix.) They may be provisionally referred to the lower group of the calciferous sandstone series—the base of the carboniferous system of Scotland.

Permian.

32. The Permian area in this Sheet extends from a mile and a half north of Kirkcolm, southwards to within a short distance of the hamlet of Lochans, two miles south of Stranraer. It forms a narrow band about eight miles in length, with an average breadth of about a mile, stretching along the western shore of Loch Ryan. It consists entirely of a coarse dark red breccia, lying unconformably on the carboniferous sandstones which divide it from the surrounding Silurian rocks. It is best exposed along the shore from its northern boundary to Corsewall House, where it forms a line of cliffs 150 feet high at the highest point. These are very much split up and broken by joints and weathering; and along the base of the higher cliffs numerous caves have been tunnelled out by the action of the sea. The lines of stratification are marked in this breccia by thin seams of sandstone from half an inch to two inches thick, and also by the position of the stones, with their longer axis parallel to the line of bedding. The general dip of the beds is to the east or south-east, but at a low angle, those forming the line of cliff already mentioned being quite horizontal. This breccia is made up of angular or sub-angular stones, which vary in size up to about one foot in length. They have much the same appearance as the stones in boulder-clay; but though they have

been searched for striated surfaces, they have not yet furnished any. They are generally covered with a thin coating of hæmatite. This rock has been entirely derived from the waste of the surrounding Lower Silurian grits, greywackes, and shales—no fragments of the underlying carboniferous sandstones having been noticed in it. The matrix in which the stones are embedded is but scanty, and consists of red gritty sand. That this rock is of Permian age, may be inferred both from its position—lying unconformably on the carboniferous sandstones already mentioned—and from its similarity to the recognised Permian breccias of South Ayrshire and Dumfriesshire.

Igneous Rocks later than the Permian Period.

33. Of the basalt dykes, which play so important a part in the geology of some parts of the Silurian region of the south of Scotland, as between Crawfordjohn and Moffat, there is but a poor representation in this district. One is exposed on the beach about one mile south of Kirkcolm, cutting through the Permian breccia, and running nearly north and south. There is another small exposure seen two miles to the north, near Corsewall Mill, of what may be the same dyke, but it is seen nowhere between these two localities. Along the west shore a fine-grained basalt dyke crops up on the beach near the Ox Rocks, and another, some miles to the south, in a small burn near Brightpark. There are two more basalt dykes exposed at the south-west corner of the Sheet, one at the north end of Ardwell Bay, and the other a mile to the south, near Grennan Point. These dykes have all a general north and south direction, and none of them can be traced for any distance.

Drift.

34. The same evidence of ice-work, so abundant over the south of Scotland, is furnished by the surface of the present district—abrasion and striation of the rocks, boulder-clay, with sands, gravels, and erratic blocks. In spite of the thick coating of turf and peat which obscures so much of the ground, the hills present on every side that smoothed and worn aspect which marks the passage of land-ice. Frequent more or less perfectly preserved *roches moutonnées* occur throughout the district. This form of surface has in many cases not been wholly effaced, even where the rocks have been subjected to much subsequent atmospheric waste. In many places the hills appear upon a near view to be rugged and broken, but at a little distance this roughness seems to vanish, and the slopes and tops then assume the normal ice-worn aspect. These appearances are well displayed in the hilly ground overlooking the Water of Luce, and they are also very conspicuous in the neighbourhood of Portpatrick, as at Craigenlee and Cairn Pyot. Glacial striæ are seldom or never observed upon the exposed faces and tops of the hills; but in places from which the overlying drift has not long been removed, the rock generally exhibits fine parallel striæ and grooves. The general direction followed by these striæ is from north-east to south-west, but here and there striæ are observed running at right angles to these. The localities of a number of these striæ are indicated upon the Map.

35. All the lower grounds are found to be more or less concealed below a covering of drift deposits. These deposits, arranged in descending order, are as follow:—

Erratic Blocks.
Brick-Clays, containing marine shells.
Sands and Gravels. No fossils yet obtained from this group.
Till or Boulder-Clay. In the lower part of the deposit, shells, chiefly fragmentary, occur.

36. *Till or Boulder-Clay.*—This deposit varies in character according to the locality in which it occurs. Thus over the Rinns of Galloway it consists of a fawn-coloured or light brown sandy clay, quite unstratified and abundantly charged with angular and sub-angular stones, which, as a rule, are well striated. None of the stones are true erratics: as far as observed, they are all of local origin, consisting of greywacke, grit, shale, metamorphic rocks, and frequently of felstone or other intrusive rocks. The clay is not so compact and tenacious a deposit as that which is met with in carboniferous districts in central Scotland; its looser and sandier texture being probably due in part to the nature of the rocks, from the abrasion of which it has been derived. In the hilly districts, near the Water of Luce, the boulder-clay is a still more loose and earthy deposit, and the included stones are not generally so well glaciated. Many are quite angular and unpolished, and not a few are of large dimensions. Towards the high grounds the deposit assumes the character of *moraine débris*, as on the slopes which overlook Loch Ryan from the east. In some of the stiff parts of the till on the low grounds, fragmentary shells are to be met with, as at Lady Bay, Innermessan, and Sandhead. The arrangement of the till in long ridges or *drums*, corresponding generally with the trend of the striæ on the rocks, can be traced, more or less definitely marked, over the peninsula to the west of Loch Ryan and Luce Bay. These features, however, have not the same decided character by which they are distinguished farther to the east in Sheets 2 and 4.

37. *Sand and Gravel.*—These deposits are scattered here and there over the low grounds forming the Rinns of Galloway. Examples occur in the extreme north of the Sheet, and extend from Dally to Portmullin; others may be seen about Lochnawe and on Larbrax and Galdenoch Moors, near Portpatrick, around Stoneykirk, Sandhead, and Float; and in the extreme south, at Ardwell, Auchness, etc. The deposits, instead of rising into well-marked ridges or kames, as in other parts of Scotland, rather group themselves into low mounds and undulating banks. They are usually well stratified, occasionally show cross bedding, and consist of layers and beds of sand, alternating with similar deposits of gravel. They rest upon the boulder-clay. The greatest height they attain is only some 300 feet above the sea.

38. *Brick-Clays.*—In the neighbourhood of the sea, certain clays are worked for brick-making. They are usually reddish-brown in colour, tough and tenacious, and not well laminated. Here and there they have yielded a few small scattered stones, and several large boulders have been obtained during the working of the clay. Those observed consisted of greywacke, and may have come from the high grounds above the Water of Luce. At the tile-works at Clashmahew near Stranraer, the clays have yielded organic remains, a list of which will be found in the Appendix. These clays, as a rule, are not found at a greater elevation than 60 feet above the sea. At Cairnbrock, however, an unfossiliferous brick-clay is wrought at a height of 160 feet. It contains more stones than usual, is not perhaps so tough as the others, and may possibly be really only a part of the true till. At Stranraer, the clay is said to rest upon sand and gravel; at Cairnbrock, the underlying deposit consists of boulder-clay. The relation between these brick-clays and the sand and

gravel series cannot be very clearly made out; but it is most probable that the former are the younger deposits.

39. *Erratic Blocks.*—Here and there boulders of grey granite are found scattered over the surface. None of them are more than a few tons in weight; but, as much of the district has been a long time under cultivation, it is probable that many loose boulders have been removed. Those observed in the course of the Geological Survey consisted of grey granite, derived, in all probability, from the granitic high grounds of Kirkcudbright. Numbers of greywacke boulders are also scattered over the surface, many of which are no doubt true ice-floated erratics; but since the underlying rocks consist of the same materials, this point is not capable of demonstration.

Raised Beach.

40. A broad belt of low-lying and gently undulating ground extends from the shores of Loch Ryan to Luce Bay. Nearly the whole of this tract is covered with sand and gravel. Although the ground is for the most part undulating, still, an examination shows that the surface deposits are arranged in a succession of broad terraces, which are best marked at the lower levels. The lowest of these terraces is indicated upon the Map as the 25 foot beach. It is composed of shingle, gravel, and sand, with numerous remains of recent littoral shells. The higher terraces are composed of rounded gravel and sand, and, as far as known, have yielded no organic remains. Though much denuded and cut into by small brooks, they are nevertheless still sufficiently well-marked. After passing inland from the level of the 25 foot beach, we find the ground rising slowly from the level of 50 feet up to that of 75 feet, forming a long and very gentle slope. Another higher terrace occurs at a height of 90 to 95 feet. Above this height lie the slopes of boulder-clay. It is not improbable that much of the sand and gravel already described may belong to the period of these old beaches, and, if not brought together, may at least have been rearranged at the same time. Along the western shores the only patch of raised beach deposits appears immediately to the south of the Ox Rocks, where there is a thin covering of mud on the level worn surface of the rocks.

Blown Sand.

41. A strip of blown sand occurs at the head of the Bay of Luce, stretching between Sandhead and the mouth of Piltanton Burn, and extending inland to the main road between Sandhead and Glenluce. It forms hillocks and ridges covered with coarse bent.

Peat and Alluvium.

42. The high ground occupying the eastern portion of this Sheet is generally covered with considerable accumulations of turf and peat, which completely hide the underlying drift and rock, except in the beds of the streams. This growth attains its greatest thickness on the hill-tops and in intervening depressions, the peaty turf on the hill-sides seldom exceeding one or two feet in thickness. The more cultivated ground, forming the western portion of the district, also contains numerous hollows filled with peat, a considerable amount of which is cut for fuel.

43. The alluvial areas of the present Sheet are confined to the larger

stream courses, with the exception of the beaches of sand and mud which are laid bare at low tide along the shores of the Bay of Luce and Loch Ryan. The chief patches of fluviatile alluvium occur in the lower course of Piltanton Burn between Barsolus and Whitecrook, and up the valley of the Water of Luce.

ECONOMIC MINERALS.

44. *Building Stones.*—Yellowish and red sandstone has been quarried for building purposes in the carboniferous band at Challoch Hill near Leswalt, and near Meikle Mark, about a mile south-west from Stranraer, but it is too soft and friable to be of any value. Some of the beds of greywacke are available for building, and quarries have been opened in them at different points along the coast. The largest is in the metamorphic area at Portpatrick. Most of the houses in the village and the greater part of the pier and dock have been built of stone from this quarry. A band of grey shales and flags at Cairn Ryan has long been worked for roofing and paving purposes. They are not true slates, however, as they have no traces of cleavage, but split along the lines of bedding.

45. *Road-metal.*—The greywacke and gritty rocks are suitable for road-metal, for which they are used on account of their toughness and durability. Some of the felstone dykes and bosses are also used for this purpose.

46. *Lead.*—Some thin veins of galena have been found on Knockibae Hill, to the north of New Luce. These have been worked for lead at Knockibae mines; but, owing to the scarcity of the mineral and the expense of working, the mines have been abandoned.

APPENDIX.

I.—LIST OF LOCALITIES

FROM WHICH FOSSILS HAVE BEEN COLLECTED BY THE GEOLOGICAL SURVEY IN THE WESTERN PART OF WIGTOWNSHIRE.—(Sheet 3.)

The numbers are those by which the localities are denoted in the succeeding List of Fossils.

Glacial.

Brick-Clays, ...	1. Clashmahew Tile Works, 1 mile S. of Stranraer.
	2. Culmore Tile Works, 1¼ mile S. of Stoneykirk.
Till or Boulder-Clay, . .	3. Lady Bay, 2 miles N. of Kirkcolm.
	4. Innermessan (Escarpment of Till), 2½ miles N. by E. of Stranraer.
	5. Sandhead (Escarpment of Till), 2 miles S. of Stoneykirk.

Carboniferous.

Red Sandstones, probably belonging to Calciferous Sandstone series.	6. Craigoch Burn, Loch Connel, 1 mile S.W. of Kirkcolm.
	7. Small Burn near Low Knockglass, 1½ mile S.W. of Stranraer.

Lower Silurian.

Upper Black Shale Group, .	8. Morroch Bay, 1½ mile S. of Portpatrick.
	9. Burn E. of Colfin, 3 miles S. of Stranraer.
	10. Gabsnout Burn, 2½ miles S. of New Luce.
	11. Shore near Clachan Heughs, at junction of Permian breccia, 1½ mile N. of Kirkcolm.
Dalveen Group, ...	12. Cairn Ryan Quarries.
	13. Portayew Cliffs, 3½ miles W. by S. from Stoneykirk.
Lower Black Shale Group, .	14. Grennan Point, Drumbreddan Bay, 6 miles S. of Stoneykirk.

II.—LIST OF FOSSILS

FROM WESTERN PART OF WIGTOWNSHIRE.—(Sheet 3.)

Glacial.

Brick-Clays.

Class, etc.	Name.	Locality Number.
Lamellibranchiata, .	Astarte.—*Sp.*	1.
	Cardium edule.—*Lin.*	
	,, Norvegicum.—*Spengler*, . . .	
	Cyprina Islandica.—*Lin.*	
	Leda truncata.—*Brown*, ...	

Class, etc.	Name.	Locality Number.
Gasteropoda,	Littorina—*Sp.*	1.
	Natica Montacuti.—*Forbes,*	

At *Loc.* 2, shell fragments were obtained—too fragmentary to be determined.

Sands and Gravels.

[No Fossils yet noticed from this subdivision.]

Boulder-Clay or Till.

Class, etc.	Name.	Locality Number.
Foraminifera,	Polystomella striato-punctata.—*F. & M.*	4, 5.
Lamellibranchiata,	Astarte.—*Sp.*	3.
	,, sulcata.—*Da Costa,*	4.
	,, compressa.—*Montagu,*	
	,, ,, var striata.—*Mull.*	
	Cardium Norvegicum.—*Spengler,*	
	Cyprina Islandica.—*Lin.*	
	Leda (*like* pernula.—*Müller*),	
	Mytilus (*probably* modiolus.—*Lin.*),	
	Tapes.—*Sp.*	
	Tellina crassa.—*Gmelin,*	
	Venus.—*Sp.*	
Gasteropoda,	Littorina littorea.—*Lin.*	
	Pleurotoma turricula.—*Montagu,*	
	Turritella.—*Sp.*	

Carboniferous.

Red Sandstones, probably belonging to the Calciferous Sandstone series.

The organic remains from the carboniferous beds of Loch Ryan consist, with one exception of plant remains, in anything but a good state of preservation. The exception referred to appears to be the remains of an encrinital stem. The specimen from locality 7 is, however, far too indefinite for a decided opinion to be passed upon it.

Class, etc.	Name.	Locality Number.
Plantæ,	Alethopteris (*Pecopteris*) lonchitidis.—*Sternb.*	6.
	Asterophyllites (*like* dubia.—*Brong.*),	
	Poacites (linear plant-*like*),	
	Calamites dubius.—*Brong.*	
	Stigmaria (*like* ficoides.—*Brong.*), with rootlets attached,	7.

Lower Silurian.

Upper Black Shale Group.

Class, etc.	Name.	Locality Number.
Hydrozoa,	Dicellograptus anceps.—*Nicholson,*	10.
	,, *Sp.*	10.
	Dicranograptus Clingani.—*Carruthers,*	8.
	,, ramosus.—*Hall,*	10.
	Diplograptus mucronatus.—*Hall,*	8, 9.
	,, pristis.—*Hisinger,*	8, 9, 10.
	Graptolithus tenuis ?—*Portlock,*	10.
	,, *Sp.*	10.

Lowther Group.

[No Fossils yet obtained from this subdivision within the area embraced by the Map.]

Dalveen Group.

Class, etc.	Name.	Locality Number.
Hydrozoa,	Climacograptus scalaris.—*Lin.*	11.
	Dicellograptus Moffatensis.—*Carruthers,*	12.
	,, *Sp.*	12.

Hydrozoa,	Dicranograptus Clingani.—*Carruthers,* .	11.
	,, *Sp.*	13.
	Diplograptus pristis ?—*Hisinger,* .	11, 12.
	Graptolithus (*like* latus.—*M'Coy.*), .	12.
	,, *Sp.*	12.

Queensberry Group.

[No Fossils yet obtained from this subdivision within the area embraced by the Map.]

Lower Black Shale Group.

Hydrozoa,	Dicranograptus ramosus.—*Hall,*	14.
	Diplograptus tamariscus.—*Nicholson,* . .	
	,, pristis.—*Hisinger,* . . .	
	Graptolithus.—*Sp.*	
	Rastrites peregrinus.—*Barrande,* . . .	

Ardwell Group.

[No Fossils yet obtained from this subdivision within the area embraced by the Map.]

In the collections made by the Geological Survey from the present Silurian area, no remains of mollusca or other organisms besides graptolites have been detected, although in the paper by Mr. Carrick Moore, cited in the Preface, two species are mentioned—one which 'appears to be the cast of a *Mytilus*,' in slaty shales and flags at Portobello Bay, near Cairnbrock, north of Portpatrick, and a shell from red slate on the shores of Loch Ryan, recognised by the late Mr. Salter as *Euomphalus furcatus*, M'Coy., common to the Llandeilo flags of Wexford and Cardiganshire. In the list accompanying that paper, two species of graptolites are mentioned which have not been observed in the Survey collection, viz. *Diplograptus folium*, His., and *Didymograptus sextans*, Hall.

III.—LIST OF FOSSILS

COLLECTED BY THE GEOLOGICAL SURVEY FROM THE SILURIAN ROCKS OF THE SOUTH-WEST OF AYRSHIRE.—(Sheets 7, 8, and 14.) [1]

1. *High Mains, about* 6 *miles N.E. of Girvan.*—(Sheet 14.)

Nidulites favus.—*Salter.*
Favosites aspera.—*D'Orb.*
Heliolites interstinctus.—*Wahlenberg.*
,, tubulatus.—*Lonsdale.*
Petraia elongata.—*Phillips.*
Ptilodictya costellata.—*M'Coy.*
Atrypa hemispherica.—*Sow.*
Leptæna tenuicincta.—*M'Coy.*
Orthis calligramma.—*Dalman.*
,, reversa.—*Salter.*
Orthonota simplex.—*Portlock.*
Macrocheilus elongatus.—*Portlock.*
Murchisonia cancellata.—*Sow.*
,, elongata ?—*Portlock.*
Maclurea Logani.—*Salter.*

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[1] The fossils comprised in this preliminary list were collected by R. Gibbs in 1863–4, and were examined conjointly by Mr. R. Etheridge, Palæontologist to the Geological Survey, and Professor Young. Those from the localities marked with an * were subsequently collected by A. Macconochie, and identified by Mr. R. Etheridge, jun.

2. *Kirk Hill, about half a mile N. of last locality.*—(Sheet 14.)

Nidulites favus.—*Salter.*
Heliolites interstinctus.—*Wahlenberg.*
,, tubulatus.—*Lonsdale.*
Petraia æquisulcata.—*M'Coy.*
,, elongata.—*Phillips.*
Illænus Thomsoni.—*Salter.*
Atrypa hemispherica.—*Sow.*
Leptæna tenuicincta.—*M'Coy.*
Holopella obsoleta.—*Sow.*

* 3. *Little Burn, S.W. of High Mains.*—(Sheet 14.)

Calymene.—*Sp.*
Trinucleus seticornis.—*Hisinger.*
Orthis elegantula.—*Dalman.*
Pterinea Sowerbyana.—*M'Coy.*
Cardiola striata.—*Sow.*
Orthoceras.—*Sp.*

* 4. *Quarry at Pond, S.W. of Rough Neuk, about 6½ miles N.E. of Girvan.*—(Sheet 14.)

Favosites.—*Sp.*
Petraia subduplicata, var crenulata.—*M'Coy.*
Glyptocrinus? basalis.—*M'Coy.*
Calymene Blumenbachii.—*Brong.*
Meristella angustifrons.—*M'Coy.*
Orthis.—*Sp.*
Strophomena.—*Sp.*

* 5. *Quarry at Rough Neuk.*—(Sheet 14.)

Nidulites favus.—*Salter.*
Petraia bina.—*Lonsdale.*
Calymene Blumenbachii.—*Brong.*
Ptilodictya.—*Sp.*
Meristella angustifrons.—*M'Coy.*
Orthis calligramma.—*Dalman.*

* 6. *Roadside near Old Fort, at Kirkhill.*—(Sheet 14.)

Meristella angustifrons.—*M'Coy.*
Strophomena.—*Sp.*

* 7. *Quarry on roadside east of Old Fort, at Kirkhill.*—(Sheet 14.)

Illænus Bowmanni.—*Salter.*
Orthis calligramma.—*Dalman.*

* 8. *Little Burn, Quarrel Hill, near Auldthorn, about 6 miles N.E. of Girvan.*—(Sheet 14.)

Meristella angustifrons.—*M'Coy.*
Orthis calligramma.—*Dalman.*
Strophomena (expansa or grandis).
Loxonema.—*Sp.*

9. *Drummuck Burn, about 4 miles N.E. of Girvan.*—(Sheet 14.)

Diplograptus pristis.—*Hisinger.*
Serpulites lougissimus.—*Murchison.*
Ampyx rostratus.—*Sars.*
Calymene Blumenbachii.—*Brong.*
Illænus Bowmanni.—*Salter.*
Phacops.—*Sp.*
Proetus.—*Sp.*
Trinucleus seticornis.—*Hisinger.*
Lingula attenuata.—*Sow.*
Orthis elegantula.—*Dalman.*
Ctenodonta.—*Sp.*
Orthonota.—*Sp.*

Leptodomus.—*Sp.*
Holopella obsoleta.—*Sow.*
Raphistoma lenticularis.—*Sow.*
Bellerophon acutus.—*Sow.*
,, carinatus.—*Sow.*
,, perturbatus.—*Sow.*
,, trilobatus.—*Sow.*
Conularia elongata.—*Portlock.*
Theca corrugata.—*Salter.*
,, triangularis.—*Portlock.*
,, vaginula.—*Salter.*
,, 2 *Sp. undt.*

* 10. *Lady Burn, a little above Drummuck.*—(Sheet 14.)

Calymene Blumenbachii.—*Brong.*
,, tuberculosa.—*Salter.*
Proetus latifrons.—*M'Coy.*
Trinucleus seticornis.—*Hisinger.*
Orthis elegantula.—*Dalman.*
Holopella.—*Sp. ?*
Murchisonia pulchra.—*M'Coy.*
Bellerophon bilobatus.—*Sow.*
,, perturbatus.—*Sow.*
,, trilobatus.—*Sow.*

* 11. *Lady Burn, opposite Threave.*

Calymene Blumenbachii.—*Brong.*
Bellerophon bilobatus.—*Sow.*
,, trilobatus.—*Sow.*

12. *Craighead Quarry, about* 3 *miles N.E. of Girvan.*—(Sheet 14.)

Nidulites favus.—*Salter.*
Favosites fibrosus.—*Goldfuss.*
Heliolites favosus.—*M'Coy.*
Petraia æquisulcata.—*M'Coy.*
,, elongata.—*Phillips.*
Encrinurus punctatus.—*Brünn.*
Discina rugata.—*Sow.*
Leptæna sericea.—*Sow.*
,, transversalis.—*Dalman.*
Lingula ovata.—*M'Coy.*
Orthis biforata.—*Schlotheim.*
,, calligramma.—*Dalman.*
,, filosa.—*Sow.*
Raphistoma lenticularis.—*Sow.*
Orthoceras politum.—*M'Coy.*

13. *Craigens, W. of Kirkhill, about* 5½ *miles N.E. of Girvan.*—(Sheet 14.)

Nidulites favus.—*Salter.*
Dictyonema sociale.—*Salter.*
Favosites asper.—*D'Orb.*
Heliolites interstinctus.—*Wahlenberg.*
,, tubulatus.—*Lonsdale.*
Petraia æquisulcata.—*M'Coy.*
,, elongata.—*Phillips.*
Tentaculites Anglicus.—*Salter.*
Ptilodictya costellata.—*M'Coy.*
Atrypa reticularis.—*Lin.*
Leptæna tenuicincta.—*M'Coy.*
Meristella angustifrons.—*M'Coy.*
Orthis calligramma.—*Dalman.*
,, confinis.—*Salter.*
,, elegantula.—*Dalman.*
,, reversa.—*Salter.*
Strophomena compressa.—*Sow.*
,, pecten.—*Lin.*
Holopella obsoleta.—*Sow.*

14. *Ardmillan Braes, about 2½ miles S.W. of Girvan.*—(Sheet 7.)

Favosites fibrosus.—*Goldfuss.*
Petraia elongata.—*Phillips.*
Asaphus gigas.—*De Kay.*
,, rectifrons.—*Portlock.*
Bronteus Hibernicus.—*Portlock.*
Illænus Bowmanni.—*Salter.*
Staurocephalus globiceps.—*Portlock.*
Stygina latifrons.—*Portlock.*
Discina oblongata.—*Portlock.*
,, ,, ,, var.
Leptæna scissa.—*Salter.*
,, sericea.—*Sow.*
,, tenuicincta.—*M'Coy.*
Orthis calligramma.—*Dalman.*
,, elegantula.—*Dalman.*
Rhynchonella cuneata.—*Dalman.*
Strophomena aranacea.—*Salter.*
,, expansa.—*Sow.*
,, grandis.—*Sow.*
Ambonychia.—*Sp.*
Arca Edmondiæformis?—*M'Coy.*
Ctenodonta.—4 *Spp. undt.*
Cucullella.—*Sp.*
Modiolopsis modiolaris.—*Conrad.*
,, 2 *Spp. undt.*
Cyclonema crebristria.—*M'Coy.*
,, *Sp.*
Ophileta compacta.—*Salter.*
Raphistoma lenticularis.—*Sow.*
,, *Sp.*
Bellerophon acutus.—*Sow.*
,, carinatus.—*Sow.*
Ecculiomphalus minor.—*Portlock.*
,, Scoticus.—*M'Coy.*
Theca reversa.—*Salter.*
,, triangularis.—*Salter.*
,, vaginula.—*Salter.*
Orthoceras ibex.—*Sow.*
,, imbricatum.—*Wahlenberg.*

15. *Piedmont Glen, S. of Girvan.*—(Sheet 7.)

Diplograptus pristis, *Hisinger*, var bullatus, *Salter.*

16. *Laggan Burn, about 1½ mile S.E. of Girvan.*—(Sheet 7.)

Diplograptus pristis.—*Hisinger.*

17. *Ardwell Shore, about 3 miles S.W. of Girvan.*—(Sheet 7.)

Cytheropsis Aldensis.—*M'Coy.*
Conocardium dipterum.—*Salter.*
Orthoceras.—*Sp.*

19. *Penwhapple Glen, E. by S. of Girvan.*—(Sheet 7.)

Favosites asper.—*D'Orb.*
Ampyx mammillatus.—*Sars.*
Bronteus Hibernicus.—*Portlock.*
Cybele verrucosa.—*Dalman.*
Encrinurus punctatus.—*Brünn.*
Illænus Bowmanni.—*Salter.*
Glyptocrinus? basalis.—*M'Coy.*
Atrypa hemispherica.—*Sow.*
,, marginalis.—*Dalman.*
,, reticularis.—*Lin.*
Leptæna sericea.—*Sow.*
,, quinquecostata.—*M'Coy.*
,, tenuicincta.—*M'Coy.*
Orthis alternata.—*Sow.*

Orthis biforata.—*Schlotheim.*
,, calligramma.—*Dalman.*
,, confinis.—*Salter.*
,, elegantula.—*Dalman.*
,, tricenaria.—*Conrad.*
,, vespertilio.—*Sow.*
Pentamerus oblongus.—*Sow.*
,, ,, var lævis.—*Sow.*
Stricklandinia lens.—*Sow.*
Strophomena depressa.—*Dalman.*
Murchisonia gyrogonia.—*M'Coy.*
Ophileta compacta.—*Salter.*
Raphistoma.—*Sp.*
Bellerophon acutus.—*Sow.*
,, bilobatus.—*Sow.*
,, perturbatus.—*Sow.*
Maclurea Logani.—*Salter.*
Lituites.—*Sp.*
Orthoceras canaliculatum.—*Sow.*

20. *Saugh Hill, about* 1½ *mile E. by S. of Girvan.*—(Sheet 8.)

Diplograptus pristis.—*Hisinger.*

21. *Camregan Plantation, about* 2 *miles E. of Girvan.*—(Sheet 8.)

Atrypa hemispherica.—*Sow.*
Pentamerus oblongus.—*Sow.*

22. *Balclatchie, about* 4 *miles E. by S. of Girvan.*—(Sheet 8.)

Favosites asper.—*D'Orb.*
Heliolites interstinctus.—*Wahlenberg.*
,, tubulatus.—*Lonsdale.*
Petraia elongata.—*Phillips.*

23. *Tramitchell, about* 3 *miles S.E. of Girvan.*—(Sheet 8.)

Tentaculites ornatus.—*Sow.*
Atrypa hemispherica.—*Sow.*

24. *Barbae, nearly* 3 *miles S.E. of Girvan.*—(Sheet 8.)

Nidulites favus.—*Salter.*
Favosites fibrosus.—*Goldfuss.*
Petraia bina.—*Lonsdale.*
Glyptocrinus? basalis.—*M'Coy.*
Maclurea Logani.—*Salter.*

25. *Pinmacher, about* 2½ *miles S. of Girvan.*—(Sheet 7.)

Heliolites favosus.—*M'Coy.*
Graptolithus priodon.—*Bronn.*
Maclurea Logani.—*Salter.*

26. *Letterpin, nearly* 4 *miles S. of Girvan.*—(Sheet 7.)

Nidulites favus.—*Salter.*
Favosites fibrosus.—*Goldfuss.*
Diplograptus pristis.—*Hisinger.*
,, ramosus.—*Hall.*
Graptolithus priodon.—*Bronn.*
Leptæna sericea.—*Sow.*
,, tenuicincta.—*M'Coy.*
Orthis reversa.—*Salter.*

27. *Auchensoul, about* 5 *miles S.E. of Girvan.*—(Sheet 8.)

Heliolites favosus.
Lingulella Davisii?—*Salter.*
Cleidophorus.—*Sp.*

28. *Aldons, about* 5 *miles S. of Girvan.*

Cytheropsis Aldensis.—*M'Coy.*
Murchisonia.—*Sp.*
Maclurea Logani.—*Salter.*

* 29. *Head of burn, passing Bargany Pond, about* 6 *miles E. by N. of Girvan.*—(Sheet 8.)

Graptolithus.—*Sp.*
Chondrites (like verisimilis.—*Salter*).
Lingula Symondsii.—*Salter.*

* 30. *Hillside opposite Blair Farm, about* 8½ *miles N.E. of Girvan.*—(Sheet 14.)

Graptolithus.—*Sp.*
Retiolites Geinitzianus.—*Barrande.*
Beyrichia Klœdeni.—*M'Coy.*
,, impendens.—*Jones.*
Lingula Symondsii.—*Salter.*
Orthis.—*Sp.*
Cardiola fibrosa.—*Sow.*
Orthoceras subundulatum.—*Portlock.*

* 31. *Quarry on roadside near Knockgardner, about* 10 *miles N.E. of Girvan.*—(Sheet 14.)

Beyrichia Klœdeni.—*M'Coy*, var.
Dictyocaris.—*Sp.*
Primitia.—*Sp.*
Pterinea pleuroptera.—*Conrad.*
Orthonota truncata.—*M'Coy.*
Grammysia.—*Sp.*

Note.—The *Entomostraca* recorded from localities 30 and 31 were kindly determined by Professor Rupert Jones, F.R.S. They are Upper Silurian forms, one—*B. Klœdeni*, M'Coy—being very characteristic of the Lesmahagow beds, the other—*B. impendens*, Jones—equally so of the Pentland Hill deposits. Accompanying the above, from locality 30, Professor Jones has recognised an apparently new Entomostracan, the only analogue of which is an undescribed form from the Pentland Hills; but there appear to be important differences between the two. Unfortunately, the remains yet obtained from locality 30 are only in the form of casts.

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SCOTLAND.

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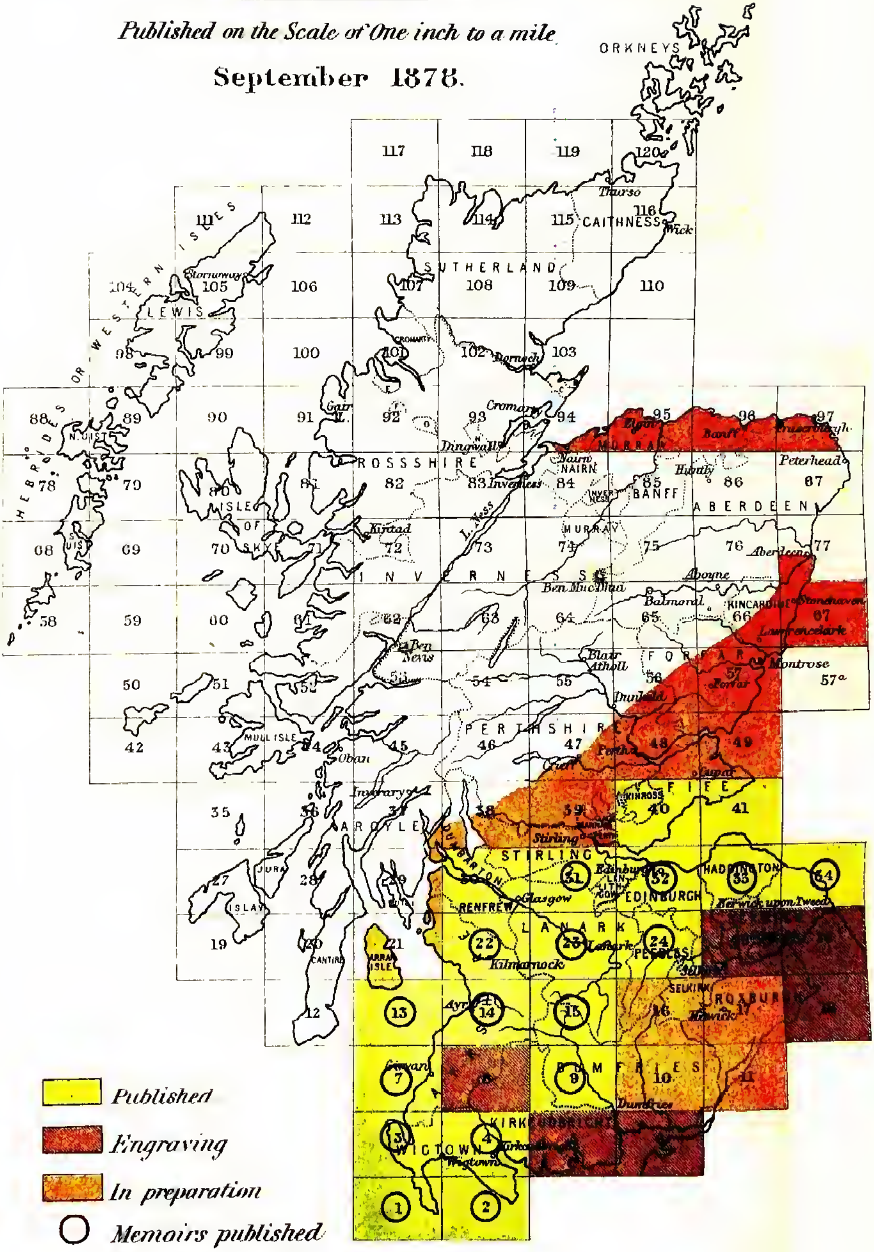

Memoirs of the Geological Survey,

SCOTLAND.

EXPLANATION OF SHEET
4.

WIGTOWNSHIRE (EAST PART).
KIRKCUDBRIGHT (PORTION OF WESTERN DIVISION).

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PREFACE.

THE Map illustrated by the present Explanation has been surveyed by Mr D. R. Irvine, with the exception of some square miles of granite to the east of Cairnsmore, traced by Mr John Horne. The ground south of Wigtown was partly worked out by the late Mr James Craik, but has been re-examined and completed by Mr Irvine, who has also written the Explanation. The Appendix of Fossils has been prepared by Mr Robert Etheridge, jun. I have, as usual, supervised the mapping of the ground, and edited the following descriptive account of the results obtained. The area has not been the subject of any previous important special memoirs. The papers referred to in the Preface to the Explanation of Sheet 3, and in the Appendix to the Explanation of Sheet 9, embrace those to which reference may be made.

ARCH. GEIKIE.

GEOLOGICAL SURVEY OFFICE,
EDINBURGH, *April* 1878.

EXPLANATION OF SHEET 4.

I. AREA EMBRACED IN THIS MAP.

1. This Sheet contains an area of 358·6 square miles, about two-thirds of which lie in the county of Wigtown, the remainder being in Kirkcudbrightshire.

It is approximately bounded on the west by the valley of the Main Water of Luce and the shore of Luce Bay; on the east by the Little Water of Fleet and Wigtown Bay; along the north edge it extends from the source of the Fleet, by Loch Grennoch and Auchinleck, to the Loch of Cree at Glenhapple; westwards by the village of Knowe on the Snap to the source of the Tarf Water in the Blood Moss. The south edge of the Sheet cuts across the lower portion of Wigtownshire from Port William on Luce Bay to Palmallet Point on Wigtown Bay.

II. FORM OF THE GROUND.

2. The area embraced in this Sheet forms the south-west extremity of the great stretch of hilly ground extending from the German Ocean to the Irish Channel, and known as the southern uplands of Scotland. Nearly two-thirds of the whole district consist of hilly ground and moorlands, covered with heather and peaty turf. The line of railway from Newton-Stewart to Glenluce may be taken as a rough boundary between the high and low grounds, most of the cultivated area lying to the south of this line. No well-marked range of hills traverses this Map; the high ground consists rather of irregular and independent ridges.

3. On looking at the Map it will be seen by the darker shading that the highest ground in the district lies in the north-east corner, to the east of the river Cree. This river forms the boundary between Wigtownshire and Kirkcudbrightshire, and from its source to where it enters the sea in this Sheet it flows between the base of the mountainous elevations of Cairnsmore and the Kells on the one side, and the lower and flatter moors of Wigtownshire on the other. In the centre of the Kirkcudbrightshire portion of the Sheet rises the great granite mass of Cairnsmore of Fleet, which reaches the height of 2331 feet. This is the greatest elevation attained in the present Sheet, save on the south-west side. It is surrounded by hills, most of which are higher than those of Wigtownshire. The most prominent amongst them are Fell of Fleet (1544) and Craig Whinnie (1250 feet) to the east, and Pibble Hill, Cambret Hill (1150), Cairnharrow (1497), and Larg Hill (969 feet) to the south.

To the west of the Cree none of the hills reach a height of 1000 feet above the sea. The most important of them occur as solitary eminences far apart from one another, the highest being Airyglasson (708), Balmurrie Fell (807), and Artfield Fell (888) in the north-west; Culvennan Fell (702), Barskeoch (579), Barraer Fell (401), Knock of Luce (513), and Craigeach Fell (426), in the centre; and Mochrum Fell (646) and Bennan (500 feet) in the south-west. Though the high grounds are arranged in no regular order, yet the contour of the whole district bears a strong relation to the character of the underlying rocks. Thus, the greater portion of the low cultivated area lies among the rocks of the Ardwell series, which, from their shattered and jointed nature, easily yield to the influence of the weather, and do not form very prominent features; while all the hills mentioned as occurring in the centre of the Sheet have a rough craggy outline, and are composed of the thick tough grits of the Queensberry group. The high grounds in the north-west corner owe their elevation to the occurrence of some thick grits in the Dalveen series, and also to the presence of the bands of fine conglomerate, called the Haggis rock, which pass through their centre. Those beds offer much more resistance to the action of the weather than the surrounding softer flags and shales, and are left rising from among them as prominent hills. The highest ground in the Sheet (Cairnsmore of Fleet) is composed of hard tough granite, which breaks up and wears away much more slowly than the stratified rocks. The beds comprising the high hills to the south of Cairnsmore are part of the Ardwell group, but they have been so hardened as to become very tough and durable.

4. There is no tract of flat ground of any extent in this Sheet, with the exception of some square miles of raised beach and alluvium at the mouth of the Cree. The cultivated area of Wigtownshire south of the railway consists of undulating hillocky ground, arranged in ridges and hollows, running in a general north-east and south-west direction—the contour presented by the districts where the Ardwell group of rocks in the Lower Silurian series occur all over the southern uplands. This district is locally known as "The Machars" of Wigtownshire, a similar tract of low ground on the west side of Luce Bay (Sheet 3) being called "The Rhins."

5. A considerable extent of ground has been brought under cultivation north of the railway near Glenluce, Newton-Stewart, and Creetown, and along the north shores of Wigtown Bay, while tracts of rich alluvial land occur up the valleys of the main streams. A peculiar feature of the Wigtownshire portion of this Sheet is the occurrence of sharply-defined ridges of boulder clay, called "Drums," often rising up as single mounds from bare rocky moors. These will be noticed in the description of the drifts. Some large flat peat mosses lying among clusters of those drums near Glenluce are also very marked features.

6. The coast-line along the shores of Wigtown Bay forms precipitous cliffs here and there, which show good sections of the rocks. From the east edge of the Sheet round Fleet Bay and westwards to Ravenshall the shore rises into a continuous line of rocky cliffs, which for most of the distance seldom exceed 30 feet in height. Between Kirkclaugh and Ravenshall, however, they rise to fully 100 feet. Another line of steep cliffs, from 50 to 100 feet high, running along the west side of the bay, from Innerwell to the south edge of the Sheet, is interrupted by the two bays of Garlieston and Cruggleton, which mark the position of some bands of soft shales and flags, and owe their formation to the ease with which these beds wear away. On the shores of Luce Bay, in the south-west corner of the Sheet, a continuous line of cliff extends for over 3 miles, from Kilfillan at the edge of the Map to Auchenmalg Bay. At Sinniness it forms a precipitous face 150 feet above the sea, though as a rule the height varies from 50 to 80 feet. The rest of the coast-line consists

of banks of boulder clay, rising from a flat shingly beach. Large flats of mud and sand are exposed at low tide at the head of Wigtown Bay and in Fleet Bay.

7. The main lines of drainage in this Sheet are those of the Cree, Bladenoch, and Tarf. Besides these, several large streams drain considerable independent areas—Palnure Burn and Moneypool Burn, which run into the tidal waters of the Cree, and the Water of Fleet and Skyre Burn, which empty themselves iuto Fleet Bay, being the most considerable. The Bladenoch with its tributaries drains the largest area. It has a very winding, sluggish course of about 25 miles from the north edge of the Map to where it enters the sea at Wigtown. All the larger streams, with the single exception of Moneypool Burn near Creetown, occupy transverse valleys, running from N.N.W. to S.S.E., more or less at right angles across the strike of the Silurian rocks.

8. The best example of a narrow rocky valley, due to stream erosion, is that of the Palnure Burn. From the north edge of the Sheet to Bargaly, this stream flows through a deep, narrow glen, which it has worn through the rocks across their line of strike. Between Dallash and Bargaly Farm it forms some striking gorges, where the channel contracts to a width of 35 feet between precipitous walls of rock. Several of the smaller streams also have worn deep channels through the drifts and the softer varieties of rock. A very good instance, seen from the road near Ravenshall, occurs at the Kirkdale Burn, which has there cut a ravine about 50 feet deep through the Ardwell rocks.

III. (9.) FORMATIONS AND GROUPS OF ROCK ENTERING INTO THE GEOLOGICAL STRUCTURE OF THE DISTRICTS SHOWN UPON THIS MAP.

Aqueous.

		Sign on Map.
Recent and Post-Tertiary.	Alluvium, Peat, Raised Beaches.	
Drift Series.	Moraines, Erratic Blocks, Sand and Gravel, Till or Boulder Clay, with Ice-worn Rock surfaces,	
Lower Silurian Llandeilo.	Carsphairn Group, Upper or Lead Hills Black Shale Group, Lowther Group, Dalveen Group, Lower or Moffat Black Shale Group, Ardwell Group, . . .	b^2

Metamorphic.

Altered Silurian Rocks passing from Schistose Greywackes into fine-grained Gneiss, . .	β^3

Igneous.

		Sign on Map
Of (?)Miocene age,	Basalt in Dykes,	B
Associated with Lower Silurian Rocks,	Dioritic Rocks, Felstones, Granite,	Di F G

IV. GEOLOGICAL STRUCTURE OF THE DISTRICTS EMBRACED IN THIS MAP.

10. The whole of this Map, with the exception of the areas of granite and other igneous rocks, is occupied by strata of Lower Silurian age, which cross the Sheet in parallel bands from south-west to north-east. The only granite mass of any extent lies round Cairnsmore of Fleet, and occupies the north-east corner of the Sheet. Two other narrow strips are exposed some miles to the south of the main mass, stretching inland in a north-east direction from the mouth of the Cree. One of these lies about a mile and a half south of Creetown; the other extends from Burnfoot up the Carsluith Burn. Round the main mass runs a belt of metamorphosed strata of varying breadth. Numerous veins and a few larger intrusive bosses of various igneous rocks rise through the Silurian groups.

Lower Silurian.

11. In the area embraced by the present Map, forming part of the Silurian uplands of the south of Scotland, the rocks, so far as can be determined from their position and fossil contents, may all be assigned to the Llandeilo formation. Good sections are obtained here and there along the shores of Luce Bay and Wigtown Bay; but the arrangement and character of the rocks are best seen by traverses across the bare hummocky moors which occupy most of the district. Some of the transverse valleys, such as those of the Bladenoch and Tarf, also show pretty continuous exposures. The strike of the beds is in the same general direction as prevails over the whole Silurian area, namely, from south-west to north-east. The successive rock groups in the Llandeilo series which have now been made out by the Geological Survey over the south of Scotland have also been established in this area. On examining the Kirkcudbrightshire side of the Map, from Fleet Bay along the north-east side of the Cree to the northern margin, it will be seen that the general direction of the dip of the strata is to the north-west, showing an ascending series in that direction. The same beds continue to the south-west right across Wigtownshire, but there the dips become much more confused, owing to the increased crumpling and folding of the strata. This is easily noticed where well-marked bands, like the black shales, are seen folded back on each other. In the north-west corner of the Map, along a line from Camrie by Loch Ronald to Glenhapple, the upper black shales lie in a synclinal trough, which extends into Sheet 8, where it runs out against the Loch Dee granite.

12. The following table shows the names and the order of succession, with the nature, relations, and roughly-estimated thicknesses of the various groups. It will be seen to correspond generally with that given in the Explanations of 3 and 9 :—

(7.) CARSPHAIRN GROUP.—Fine conglomerates and coarse grits, with thick greywackes and shale partings.

(6.) UPPER BLACK SHALES.—Black shales, containing graptolites, with bands of chert and grey and purplish shales. Estimated thickness, 450 feet.

(5.) LOWTHER GROUP.—A set of soft grey shales, with grey and blue flags and greywacke bands.

(4.) DALVEEN GROUP.—A set of jointed greywackes, with grey and blue flags and shales, including a band of fine pebbly conglomerate, called the "Haggis Rock." Estimated thickness of Lowther and Dalveen groups together, 2500 feet to 3000 feet.

(3.) QUEENSBERRY GROUP.—Thick massive grits and greywackes, with regular jointings. Some bands of grey and blue shales and flags. At the bottom of the series there is a considerable thickness of grey sandy shales, corresponding to the "Grieston beds," in Sheets 9, 15, and 24. Estimated thickness, 3500 to 4000 feet.

(2.) LOWER OR MOFFAT BLACK SHALE GROUP.—Black shales, with graptolites. Some bands of grey and blue shales and flags. Estimated thickness, 200 feet.

(1.) ARDWELL GROUP.—Brown-crusted red, blue, and grey jointed sandy greywackes, grey and purplish argillaceous shales, and bluish and yellow sandy shales. Thickness not ascertainable in this Sheet.

ARDWELL GROUP.

13. The strata comprised under this name extend over about one-third of the area in this Sheet. Their northern limit, formed by the most southerly outcrop of lower black shales, runs from Eldrig Loch, in a north-east direction, by Wigtown and Creetown, to the east edge of the Sheet, one mile south of the granite boundary. The whole district south of this line is occupied by Ardwell beds. Good sections are obtained along the shores of Fleet Bay and on all the hills east of Creetown. The relation of this group to the overlying black shales is best seen up the Englishman's Burn, north-east of Creetown. A narrow strip of shaly, and somewhat altered or even schistose beds, belonging to this group, occurs between the outcrops of black shale in Englishman's Burn and at Culcronchie viaduct. They are here brought up within an inverted fold of the black shales. Another narrow band of the Ardwell group, brought up in the same way by an inverted arch of the black shales, runs from Minnigaff to the edge of the Sheet at Talnotry, and consists of a set of brown-crusted, yellowish, sandy schistose shales and flaggy greywackes, well seen in the Cree below Minnigaff manse. The fold must "nose out" rapidly south of the Cree, as neither the black shales nor the underlying beds are seen to the south-west. This same arch extends across the corner of Sheet 8 into Sheet 9, in the Explanation of which it has been noticed (par. 10). The best section south of the Cree is obtained along the coast-line from Baldoon Sands to the edge of the Sheet. The cliffs, about 50 feet high, run almost at right angles to the line of strike, so that the numerous sharp folds and curves characteristic of this portion of the Silurian series are very well seen.

14. In lithological characters the Ardwell group may be described as consisting of greywacke in beds from 1 to 4 feet thick, flags and shales. So greatly have they been contorted and crumpled into sharp and often inverted folds, that it is impossible to form even a rough estimate of their thickness. From the numerous folds and reversed dips seen along the coast sections, it may be presumed that the actual depth of the group is considerably less than, from the breadth of country occupied by the strata, might be supposed. As a rule the beds of this group have a soft, brown, crumbly, weathered crust, about half an inch thick. In Kirkcudbrightshire the surface is often pale yellow, almost white, but when broken up the rock is grey or bluish in colour. In Wigtownshire again, the prevailing tint of the freshly fractured rock is red or pink. The Ardwell beds are likewise very shattery and full of joints, often filled with quartz, some-

times with calcite, or coated with hæmatite. They generally break up into small angular fragments under the hammer, but some of the more flaggy greywacke bands split regularly along the lines of bedding and make excellent building stone. The shales often show a rude cleavage in the opposite direction to the dip, and at a high angle. This is best seen along the Kirkcudbright coast-line from Carsluith to the Isles of Fleet, but it is nowhere so well developed that the shales split along the cleavage planes. In Kirkcudbrightshire the top beds of this series immediately under the black shales assume a much more shaly character than they have further to the west in Wigtownshire. This feature becomes more developed in Sheets 8 and 9 to the north and north-east.

15. This group, everywhere singularly barren in fossils, has yielded a few forms in the present district. Specimens of *Protovirgularia* have been found in some bands of grey fissile shales in Garliestown Bay; while some grey and reddish shales in the railway cutting at Whauphill have yielded numerous fragments of graptolites. Worm-tracks are also numerous in the red and grey shales exposed along the line of railway from Bladenoch Bridge south to Whauphill.

LOWER OR MOFFAT BLACK SHALES.

16. This set of beds, owing to their well-marked lithological character, form a most important subdivision of the Lower Silurian rocks. In the area included within the present Map their thickness is inconsiderable, being not more than 200 feet where they are best developed. They consist of a set of grey and blue slabs and flags, sometimes with whitish argillaceous seams like fire-clays and one or two bands of black shales. It is these black strata which form the characteristic feature of this group, both from their striking colour and from the number of graptolites which they generally contain.* So contorted and folded over are they that they often appear to have a much greater thickness than is really theirs. They frequently abound in veins of quartz.

17. In the present area this group is generally brought up along sharp anticlinal folds in the overlying Queensberry beds. The most northerly outcrop occurs at Talnotry, along the north edge of the Sheet. It runs to the south-west by Loch of the Lowes and Cumloden to the Cree below Knockstocks, where a good section is exposed, showing the crumpling of the black shales. The beds lie here along the anticline, which, as has been already noticed, brings up a portion of the Ardwell group for a short distance, but "noses out" so rapidly that the black shales do not again appear along this line south-west of the Cree. A short distance to the south, on the crest of another anticline in the Queensberry group, the black shales rise up in the Gillespie Burn near Culroy. This arch nowhere else allows such a deep part of the Silurian series to appear at the surface. Still further to the south two other exposures of black shales occur near each other at Black Loch and Crailloch, and again at Glenluig and White Dyke, along an arch at the bottom of the Queensberry beds, the folding here being great enough to expose some of the beds below the black shales themselves. The strata here are inverted, so as to dip in the same direction on both sides of the anticline, which, in the space of a mile or two, dies out to the north-east. The final outcrop in a southerly direction is seen at Eldrig Loch near the village of Eldrig. Here the black shales appear in the proper order of succession, coming on above the Ardwell beds, and passing under the Queensberry grits of Mochrum Fell. They do not again appear in Wigtownshire along this line of outcrop, pro-

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* See Explanation to Sheet 3, p. 10

bably owing to the ground being so much covered with peat and drift. Along the same line in Kirkcudbrightshire, however, they crop out in Englishman's Burn north-east of Creetown and on Pibble Hill. Immediately to the north of that outcrop they are once more thrown up in a sharp fold at Culcronchie viaduct, whence they may be traced almost continuously to the east edge of the Sheet, a distance of about 4 miles. From Pibble Hill eastwards it will be seen that the dips all point to the south-east, or contrary to the normal direction, as exhibited between Fleet Bay and Newton-Stewart. It is believed that the discrepancy must be due to an inversion of the dip.

From Creetown, northwards, along the edge of the granite, numerous outcrops of the black shales appear along sharp anticlinal folds, sometimes bringing up the upper beds of the Ardwell series. In this district the black shales, often passing from black to blue and dull grey, have been so much compressed and baked as to have become schistose, and to have completely lost all trace of the original lines of bedding. When in this altered schistose condition they become remarkable tough, and generally split up into large square blocks. No traces of graptolites have been observed in any of those altered dark shales. They are abundantly veined with quartz, and often contain quantities of iron pyrites in veins and diffused through the mass. The best exposures of the black shales in this metamorphic area occur half a mile north-east of Cranmer Hill, at the head of Cairnsmore Burn. Here, in an area not more than a quarter of a mile wide, they appear in four outcrops, separated by schists and altered greywackes, the whole of these strata invariably dipping to the north-west. In this case, also, it is evident that the apparent steady succession of beds is deceptive, and that the same portions of the group are repeated several times in inverted folds. These curvatures are well seen on the faces of several small cliffs on Bardrochwood Moor; also up the Mill Buru, east of Bardrochwood, and in the Knock Burn a little further to the north. A ridge of highly altered and schistose dark blue and black shale is seen running along the western margin of the granite boundary from Blairbuies Burn to near Dallash Cairns in an N.N.W. direction, at right angles to the normal line of strike. As shown upon the Map, the strike of these and the other adjacent strata is considerably deflected near the granite junction. This feature, which is much more marked round the Loch Dee granite (Sheet 8), is again referred to in par. 36.

QUEENSBERRY GRIT GROUP.

18. This well-marked and important group of strata is well represented in the present Sheet, where it occupies fully one-third of the total area. It occurs in a broad band, which, extending diagonally across the Sheet with an average breadth of about 9 miles, is bounded along the north by a line running north-east from Glenluce by Carscreuch, Culvennan, Barfad, and the north edge of Glenrazie Wood to Penninghame House, where it crosses the Cree, and passes into Sheet 8 near Terregan. Its southern boundary coincides with the lowest outcrop of the Moffat black shales, already traced in par. 17. The whole area included between those boundaries, with the exception of the narrow denuded anticlinal "inliers" of black shales already mentioned, is occupied by this group, which has been thrown into a series of large folds, sometimes sharp enough, as we have seen, to bring up the lower black shales along the line of axis. None of the synclinal troughs, however, are deep enough to have preserved any part of the next overlying group.

19. The Queensberry grits have here much the same characters as in Sheet 9, lying to the north-east. (See Explanation to that Sheet, par. 14.) They consist for the most part of thick massive grits and greywackes, with occasional zones of grey and blue shales. The beds are traversed by a very regular system of joints, owing to which they easily split up into square blocks and slabs, and on this account are largely quarried for building purposes, paving, &c. Fossil remains, which occur so rarely in this group, have as yet been met with only at two localities in the present district. Some bands of grey and bluish shales on the coast-line near Sinniness, south of Glenluce, have yielded fragments of graptolites; and some rather better specimens have been obtained from a bed of dark blue shale, exposed in the Tarf at Wauk Mill beside Kirkcowan.

20. This group consists of two well-marked subdivisions, which may be traced almost continuously to the north-east through Sheets 8 and 9 into Sheet 16. The lower of these lies at the bottom of the group, resting on the lower black shale, and consists of a set of grey and bluish shales, rather sandy and micaceous. These are well seen on either side of the arch of the lower black shales, between Minnigaff and the north edge of the Sheet. This anticline, as has been noticed in par. 17, dies out so rapidly to the south-west that neither the black shales, nor the lower beds of the Queensberry group are seen again south of the Cree. Above this shaly subdivision, as in the typical ground at Queensberry Hill, a succession of thick massive grits, fine pebbly conglomerates and shale bands form the remainder and chief portions of the group. Their upper beds sometimes contain well-marked bands of blue shales and flags, as at Glenluce, where they are quarried for roofing and paving purposes; but these are not at all constant, and, as a rule, the grits pass gradually up into the flaggy greywackes, constituting the Dalveen group.

21. The lower shaly zone is well exposed on the craggy hills west of the New Galloway road at Talnotry, where a constantly ascending dip to the north-west may be traced from the granite junction across the black shales into the Queensberry grits. It is here tilted up at an angle of from 65° to 80°, and covers a breadth of fully a quarter of a mile. Unless folds or reversed dips should occur which have not been noticed, this dip would give the shales a thickness of fully 1200 feet. They thin out rapidly to the south-west however, and are entirely absent in the Cree section, where their place is taken by thick greywackes, with some flaggy bands. To the north-west these beds gradually swell out so as to cover twice the breadth of ground in Sheet 8, which they occupy here. From their appearance and position, they may be considered the representatives of what have been recognised as the "Grieston beds," in Sheet 9, and the ground to the north-east. (See Explanation of Sheet 9, pars. 14 and 15.) The absence of these shales in the north-western portion of this region cannot be satisfactorily accounted for by any folding or other kind of structure which might have concealed them, for though the very lowest beds of the Queensberry group are several times brought up along lines of anticline, restiug directly upon the black shales, yet the so-called "Grieston shales" nowhere reappear, their place being occupied, as has been said, by well-bedded greywackes. The beds on the south side of the anticline of black shales, along the New Galloway road, dip in the same direction as those on the north. That this is a reversed dip is indicated by the occurrence of the same zone of "Grieston shales" on both sides. They have likewise been thrown into a small basin between Blackcraig and the granite junction, so as to enclose some of the overlying thick massive grits which are well seen on Larg Hill, and on the moor south of Glenamour Loch, where they form prominent bare rocky hummocks. The

dips on the Map from Palnure station round by Blackcraig to Larg show well the ending off of this trough. It must be remembered that between Larg and Glenamour and the black shales the dips are reversed.

22. The grits and thick beds forming the great mass of the Queensberry group can be advantageously examined in many natural sections in the present Sheet. With the exception of Cairnsmore, they form the chief ranges of hills—for instance, Eldrig, Culvennan, and Barskeoch Hills in Wigtownshire, and Glenmalloch Hill and Cumloden Deer Park in Kirkcudbright. Along their south-west boundary rise the hills of Bennan, Mochrum, and Chang Fell; while over the intervening ground the coarser and more massive beds swell up here and there into prominences, such as Knock Fell, Craigeach, and Barraer Hill. The section which perhaps best shows the characteristic features of those thick grits and massive greywackes, runs along a line of cliff called the Craigs of Garheugh, at the side of the road from Glenluce to Port-William. Cutting across the beds at right angles to their line of strike, it displays their well-defined parallel bedding, and their regular system of jointing. Another good section may be found in the valley of the Bladenoch Water, both in the channel of the stream and on the adjoining hill-sides. Few instances in this area can be seen where the pebbly grits pass into a rock coarse enough to be properly called a conglomerate. One patch of conglomerate lies on the west side of Craigeach Fell, but is only traceable for a few hundred yards. The pebbles are from ½ inch up to 4 and 6 inches in diameter, and are composed of quartz, quartz-rock, greywacke, and hardened shale. A coarser conglomerate occurs at the head of the Straminoch and Coldstream Burns on Drannandow Moor, at the extreme north edge of the Map. It passes into Sheet 8, where it is traced in broken bands of varying breadth for over a mile. The stones vary from small pebbles up to boulders 1 foot in diameter, and are almost all of quartz and altered greywackes.

23. The prevailing colour of the strata of the Queensberry group is blue and grey; but on Barr Hill, south of Newton-Stewart, a set of massive grits, with bands of shale, are all stained of a deep red and purple colour, owing to the diffusion of iron through the mass. Some of the beds are so strongly ferruginous as to have given rise to a belief that hæmatite veins existed in the neighbourhood, but, though diligent search has been made in several localities, no trace of them has yet been found.

24. In a few localities a set of blue shales and flags occurs at the top of this group, occupying the place of the "Barlae shales" in Sheet 9, of which they probably form a continuation. They may be best seen in the quarries and railway cutting immediately south of Glenluce, where they are largely worked for roofing purposes and pavements.

Dalveen Group.

25. This set of beds, which comes on immediately above the group last described, is distinguished from it by the general absence of the characteristic thick grits, and by a less regular system of jointing. It consists of a set of greywacke beds, a good deal broken up by joints, with bands of flags and grey shales. Sometimes the shales occur in bands of considerable thickness, though generally they take the form merely of thin beds and partings between the greywackes and flags. The greywackes also occasionally form thick masses with bands of grit and thin shale partings. The zone of coarse grit passing into pebbly conglomerate, so well developed in Sheet 15, and known as the "Haggis Rock," also occurs in this district. It has a coarse pebbly texture, the pebbles sometimes being ½ inch in diameter, and it passes into a fine conglomerate, with stones from the size of a pea up

to 2 and 3 inches in length. The component pebbles of the "Haggis Rock" consist, for the most part, of fragments of quartz, Lydian stone, and altered greywacke. The most important feature in this conspicuous band is its occasionally fossiliferous character. A few encrinite fragments have been obtained by the Geological Survey from the fine conglomerate near the village of Knowe, but they are badly preserved. (See Explanation to Sheet 9, par. 19.)

26. This group occupies a comparatively limited area in the present Map. It crosses the north-west corner in two bands, one on each side of the synclinal trough in which the upper black shales lie. In the southern band the beds are well exposed at Carscreuch and Grennan, north-east of Glenluce, and in the Tarf Water at Mark Broom. They have a very constant dip to the north-west, at high angles of from 60° to 80°, and are traced by Ballochadee and Barfad to the north edge of the Sheet at Wood of Cree. Along this outcrop they consist of grey shales and greywackes, with a few thick gritty bands. On the northern outcrop they rise from underneath the Lowther shale group with a south-easterly dip, and extend from Kilhern, at the west edge of the Map, north-eastward to Glassock Fell. The beds here are a good deal more massive than on the south side of the syncline; the shales occur in thinner bands, and, where the grits become thickest and most numerous, as at Artfield Fell, prominent hills, as well as ridges and bosses, rise along their outcrop. The northern band of Dalveen beds is considerably broader than the southern. This arises from the fact that the strata have here been folded up into an anticline, the axis of which runs from Drangower through Artfield Fell and Carseriggan Moor to the northern edge of the Sheet. To the north-west of this line the same beds are repeated with a north-west dip, until they again pass under the Lowther shales at Kilmacfadzean and High Eldrig. It is only along this final outcrop that the "Haggis Rock" appears. This conspicuous band is well exposed on the moor beside the village of Knowe, where it attains a thickness of about 100 feet, thinning out, however, before reaching the river Bladenoch. It reappears on the north side of Urrall Hill in two parallel bands, separated by greywackes and shales. These may be presumed to be the same band repeated by a small fold. It is again seen as a prominent feature on Eldrig Fell, and lastly crops up to the south-west through Artfield and Balmurrie Fells.

In the present area, the Dalveen and Lowther groups pass so insensibly into each other, and have likewise been so plicated together, that no satisfactory estimate can here be made of the thickness of each group by itself.

LOWTHER SHALE GROUP.

27. This group covers a still smaller area than that just described. It is seen on both sides of the synclinal trough of upper black shales (par. 26), and likewise in a third band further to the north. On the south side of the syncline, it is well seen between White Cairn and Camrie, one mile north of Glenluce, whence it extends across the Sheet to the north edge in a strip about half a mile broad. For three-fourths of this distance the beds preserve a pretty constant dip to the north-west, but between Carseriggan and the north edge of the Map they are inclined to the south-east at a high angle. This is owing to some sharp crumplings of the beds which reverse the dip. Where typically developed, the Lowther shales, as their name implies, consist mainly of shaly beds. These are generally fine-grained argillaceous, grey, brownish-yellow, and bluish in colour, with some brown sandy beds, and a few thick gritty

bands. This is the appearance which they present towards the south-west, south of the syncline, as may be well seen about Camrie, Carscreugh Fell, and Mark Broom. To the north-east, however, by Carseriggan and Glenhapple Moor, along the same line of strike, they become much more thick bedded, with several bands of grit and massive greywackes. In this condition they are undistinguishable from the underlying Dalveen group. North of the syncline, they are seen flanking the upper black shales, below which they plunge with a constant inclination to the south-east the whole way across the Map. They are well exposed on Bught Fell, Gass Moor, and Carseriggan Moor, and in the Drumpail Burn, the Tarf and the Black Burn. They here present the same thick-bedded character which they assume on parts of their southern outcrop. They consist of flags and greywackes, sometimes very massive and coarse, with here and there zones of grey shales and grey and blue flags. This thickening of the group on the north side of the syncline is a marked feature of the Lowther series, from Port-Patrick on the Irish Channel, across Sheets 3, 4, and 8 into Sheet 16, and has been described in the Explanation to Sheet 3, where it is largely developed. (See par. 17 of that Explanation.)

28. The most northerly outcrop of the Lowther shales forms a narrow band on the further side of the anticline in the Dalveen group, and extends from Kilmacfadzean by Eldrig Loch to where the Bladenoch enters the Sheet. It here consists of several bands of grey and brownish soft shales, with greywakces and flaggy beds passing insensibly into the underlying Dalveen group. Good sections are obtained on the moors near Kilmacfadzean and at Eldrig Moss and Dirneark.

29. Like the shaly zones in the Lower Silurian series of the south of Scotland, the Lowther group is here often much crumpled and folded over. Some of these folds are shown in the Map by the dips; but in many cases where the dip remains constant in one direction for a considerable distance, the same beds are observed to be brought up two or three times by sharp inverted folds. The whole series is shattered and broken up by joints in all directions, and veins of quartz are also numerous. The sides of the joints in many instances are coated with carbonate of lime, which also occurs here and there in veins. It has been already remarked that, owing to the similarity of the Lowther and Dalveen groups in this area, it has not been possible to divide them sufficiently to allow an estimate to be formed of the thickness of each separately. The thickness of the two groups together is estimated at from 2500 to 3000 feet.

UPPER OR LEAD HILLS BLACK SHALE GROUP.

30. This group bears so strong a resemblance to the lower or Moffat black shales already described, that, but for the evidence of superposition, it might readily be identified with that band. It consists of dark blue flags, grey and blue greywackes and shales, with one or two bands of black anthracitic shale, which form the conspicuous featnre of the group. The total thickness of these strata probably does not exceed 450 feet, of which the black shales perhaps do not form more than about 30 feet. This group, in spite of its general resemblance to the lower black shales, may be distinguished lithologically by the occurrence in it of bands of grey flinty flags and whitish cherts which almost invariably accompany the black shales. The beds are very much contorted and crumpled, and generally seamed in all directions with fine quartz veins. The black bands contain quantities of iron pyrites in crystals and nodules. Where-

ever exposed they are found to contain remains of graptolites. In some localities these are specially abundant, as in the Black Burn, near Drummabrennan. In other places, however, the black shales have been so much squeezed, crumpled, and broken, that traces of fossils are almost obliterated. The blue shales and flaggy bands accompanying the black shales likewise yield sometimes a few graptolites.

31. This group crosses the north-west corner of the Map in two parallel bands. Of these, the more southerly forms the centre of the synclinal trough referred to in par. 26, has a breadth of from a quarter to half a mile, and stretches from Camrie 2 miles north of Glenluce, by Balminnoch and Glassock to Glenhapple on the Cree. On either side of this basin the black shales may be seen dipping towards the centre in two parallel interrupted lines, forming nearly the base of the group. They are overlaid by blue and grey shales, flags, and greywackes, while some bands of grit appear when the trough is deep and wide enough to hold the highest beds of the series. This syncline of the upper black shales is a very well-marked one, traceable continuously from Morroch Bay, south of Port-Patrick, across Sheets 3 and 4, into Sheet 8, where it is cut off by the Loch Dee granite. As will be seen from the present Map, however, the outcrop of the black shales cannot be followed without numerous interruptions, arising no doubt chiefly, if not entirely, from the drift-covered or mossy nature of the surface. These strata are seen on both sides of the syncline at Glassock. They appear on the north margin near Carseriggan, in Black Burn, at Drummabrennan, on the road side at Balminnoch, and in one or two places between Garvilland and the edge of the Sheet; on the south margin at Ringdown and Camrie. But could the drift and peat be removed from the surface, it may be presumed that the syncline would be found flanked with a continuous strip of these very conspicuous black beds on either side across the whole Map. Generally only one single band of black shale occurs along the outcrop. On the north side of Carscreugh Hill, near Ringdown, however, there are three outcrops only separated by a few hundred feet of strata. From the vertical and intensely crumpled and twisted character of the strata, as well as from the similarity of the black shales at the different localities, it may be inferred that these three bands are merely repetitions of the usual single zone brought up by small sharp folds. The deepest part of the syncline lies at the north edge of the Sheet. There, on Glenhapple Fell, some thick massive bands of greywacke and grit rest on the black shale group. These grits become more developed along the same line of strike in Sheet 8, where the trough deepens for some distance. They form, therefore, the base of the next overlying portion of the Silurian series, to which the name of the "Carsphairn group" has been given. (See Explanation to Sheet 9, par. 26.)

32. To the north of the synclinal trough the second bar of the black shale group runs continuously from Eldrig Moss to the north edge of the Sheet. As it lies against the anticline which repeats the Dalveen and Lowther groups, it has a prevalent north-westerly dip. The black bands are very much crumpled and twisted here, and full of fine quartz veins, as may be seen in several good sections south-west of Dirneark. A few graptolites have been obtained from this locality, but the shales are too shattery and jointed to yield good specimens. They are associated with grey and shivery brown sandy shales, the latter very fissile, and splitting up into thin laminæ, and are succeeded by hard jointed greywackes and grit bands, which pass up into the overlying group.

CARSPHAIRN GROUP.

33. On looking at the Map, it will be seen that there is a constant north-westerly dip from the last-mentioned zone of upper black shales to the corner of the Sheet. This brings in the higher set of conformable beds, which have been above referred to as the Carsphairn group, so called from their large development near the village of that name (Sheet 8). They consist of a set of coarse, massive, grey and blue grits, sometimes passing into a fine conglomerate, with shale partings and bands of greywacke. They cover a large area in Sheet 8, on both sides of the central mass of granite. As they will be fully described in the Explanation to that Sheet, and as in the present Map they occupy such a small area (not more than 2 square miles altogether), the detailed description of them may be deferred. The portion of the group here visible lies at the south side of a synclinal trough, which occupies a large breadth in Sheet 8 (well exposed in the channels of the rivers Cree and Minnoch), but of which only a small part of the southern margin comes into this Sheet, and which dies out rapidly to the south-west. Good sections may be examined on Airyglasson Hill, and on the moors near Laggangairn. No fossils have been obtained from these beds in this Sheet.

Metamorphism of Silurian Areas.

34. In several districts of the present Map the Lower Silurian Rocks have undergone considerable metamorphism. The chief metamorphic area forms a zone of varying width, encircling the granite mass of Cairnsmore; but several small detached areas likewise occur at a distance from the granite mass, wherein the rocks have been more or less altered, as may be seen about Craigach Fell and the Knock of Luce in Wigtownshire. Where there has been least metamorphism, as in these last-named instances, the rocks have assumed only a slightly crystalline texture, but without any schistose arrangement of their parts. The finer-grained flaggy bands and shales have been so much hardened and baked together, that the fissile character of the shales is often lost, and they consequently break with a splintery conchoidal fracture resembling some compact igneous rocks. At the same time the beds are traversed by joints in all directions and greatly crumpled. Veins of quartz and calcite abound, while here and there a rude cleavage may be traced through some of the shale bands. As a peculiar feature of these areas of lesser metamorphism, it may be noticed that they all lie in the Queensberry grit group.

35. Much more pronounced is the alteration to be observed in another district lying between Creetown and the east edge of the Map. Considering the distance at which this area lies from the granite of Cairnsmore, its metamorphism can hardly have been due directly to the influence of that huge mass, unless, indeed, as is highly probable, the granite extends for a considerable distance at no great depth beneath the surface. In that case the lenticular patches of granite seen to the south-east of Creetown, at the edge of this metamorphic area, might be regarded as portions of one general subterranean mass exposed by denudation. The whole of this area lies in the Ardwell group. On the Cairnharrow, Benjohn, and Ardwell Hills, which lie near the centre of the same metamorphic district, at a distance of from 3 to 5 miles from the Creetown, and about 6 miles from Cairnsmore granite masses, the alteration of the strata is very well seen.

The harder quartzose greywacke bands have generally a slightly schistose texture, with a grey compact base. Mica is only sparsely developed in these bands, and occasionally quartz granules are met with. Here and there all over this area certain bands have assumed a much more schistose structure than occurs in the surrounding beds. These are very felspathic, contain little quartz, and have a white weathered surface often an inch or more in thickness, but when broken into are pale grey compact rocks. At first these altered bands might be mistaken for certain varieties of felstone dykes; but a careful examination of the rock proves them to be highly metamorphosed greywacke. The bands of shale associated with these beds, instead of the usual baked flinty texture found in the neighbourhood of the granite, present a schistose micaceous aspect, and are commonly soft and fissile. Flakes of mica, seldom seen among the Silurian rocks except round the granite bosses, form here a prominent feature of the rocks.

36. Round the main granite centre of Cairnsmore the most intense metamorphism may be seen. As the junction with that rock is approached, the Silurian strata become more and more micaceous until they pass into true schists near the edge of the mass. Where fine argillaceous shale bands occur they have been so much hardened and baked as to be converted into Lydian stone. The beds immediately round the granite belong to the Ardwell, Lower black shale, and Queensberry groups. The alteration of the black shales is well exposed in the west side of Cairnsmore Hill. They become dark blue in colour, very schistose and fibrous in texture, with an abundant diffusion of iron pyrites through their mass. So greatly have they been squeezed and baked that their bedding is quite obliterated, and the altered rock breaks up into large square blocks. It will be observed, also, that along the west side of the granite the normal strike of the beds is deflected so as to run almost at right angles to its usual course.

Igneous Rocks.

37. The Silurian rocks are here pierced by granite, felstone, and diorite, both in large disruptive masses and in many small veins or dykes. As has been already stated, the chief mass of granite is that of Cairnsmore of Fleet, one of the three large granitic bosses of Galloway, of which 30 square miles are embraced within the area of the present Map. In addition to this, three small lenticular patches or dykes rise to the south and south-west of Creetown. These patches lie near each other, and from 4 to 6 miles south of the main mass, with which, as already suggested, they may possibly be connected under ground. The general colour of the granite is grey, shading in places into a flesh colour or pink tint. The latter is most commonly met with near the edge of the mass, and may be well seen along the south and west slopes of Cairnsmore Hill, and up the valley of the Palnure Burn. The general texture of the Cairnsmore mass is extremely coarse; but in the lenticular patches to the south of Creetown a much more compact variety is met with. By far the coarsest grained examples are exposed along the top of Cairnsmore Hill. Here masses of granite may be seen with crystals of quartz and felspar upwards of 2 inches in length. Good specimens may be obtained from the large cairn of loose blocks which marks the highest summit of the hill. While the granite consists, for the most part, of quartz, orthoclase, and plagioclase felspar, black and white mica, with occasional hornblende, its lithological character varies, owing to the disappearance of one or more of the ordinary constituents.

Sometimes the mica is almost entirely replaced by the hornblende, while in many instances the quartz forms a minor ingredient. The felspar is always the chief constituent, consisting for the most part of orthoclase, but numerous striated faces are also met with. The black variety of mica, named lepidomelane, is the one most commonly occurring throughout the mass, but in some places, more particularly in the Cranmer, Craiglowrie, and Craigherron Hills, a whitish variety occurs, which may be margarodite. The crystalline form of the quartz is well marked in various localities, and especially on the top of Cairnsmore Hill, whence the hexagonal prisms with well-marked single terminations may be obtained. This, however, is exceptional, as the quartz usually occurs in an amorphous or imperfectly crystallized form. On many of the hill slopes and protruding knobs the effect of denudation is well seen in the exposed surfaces of granite, as the large quartz crystals have resisted the weathering more successfully than the felspar and mica. It is worthy of note, also, that in the Clints of Dromore small garnets occur pretty plentifully, and in one or two places crystals of sphene have been observed. Iron pyrites is also of common occurrence, chiefly in the form of yellowish or brown decomposing crystals.

38. No mass of fine-grained granite occurs anywhere in this area, but dykes and veins of the fine-grained granitic rock termed elvanite occur not only round the edges of the metamorphosed area, but all through the heart of the coarse-grained granite. Perhaps one of the best examples of these elvanite veins is to be seen in the railway cutting between Dromore station and the Water of Fleet viaduct. The rock consists mostly of white orthoclase felspar, with a small quantity of mica, iron pyrites, and quartz. In other districts of Galloway a well-marked passage from granite to hornblendic porphyry and felstone has been obtained, but in the present area this gradation is not of common occurrence. Occasionally, round the edge of the granite, and at some distance from it towards the centre of the mass, the rock may be traced through the intervening stages into compact flesh-coloured felstone with some crystals of hornblende. The junction of the granite with the surrounding schistose rocks is always sharply defined. In no case has any trace of gradation from one rock to the other been observed. Along the west edge the boundary is very irregular and broken, with numerous veins of fine-grained granite and elvanite piercing the Silurian rocks. Numerous patches of altered greywacke are seen caught up in the granite, but seldom at a distance of more than 200 yards from the edge of the mass. The largest of these is Blairbuie's Hill, and is about 200 yards long by 50 broad.

39. Besides the granite and the veins and dykes associated with it, numerous other intrusive rocks, chiefly in the form of dykes, traverse the Silurian strata throughout the area of the Map. With the single exception of a small dyke of amygdaloidal basalt near Ravenshall, these all consist of felstones and diorites. A large mass of diorite, occupying about 1½ square miles, is seen 3 miles north of Kirkcowan, between Culvennan Hill and the river Bladenoch. This is a typical diorite, consisting chiefly of plagioclase felspar and hornblende crystals, with a little quartz and iron pyrites. Two smaller masses of a similar diorite are seen a little distance to the south at Bennan and near Mark of Shennanton.

Immediately to the south of Glenluce another considerable mass of dioritic (or rather perhaps of syenitic) rock occurs. It is composed of orthoclase felspar, quartz, and hornblende, with some greenish crystals of decomposed biotite, a little iron pyrites, and a very few striated crystals of calcite. The most important dykes of diorite occur in groups, on Fell Hill near Loch Ronald, and on Craignarget Hill east of Gillespie Burn.

Other small dykes will be seen marked on the Map in different localities. They are all much the same in composition as the Culvennan Fell mass, their chief constituents being felspar and hornblende, with some quartz.

The great majority of the dykes in this Sheet belong to the class of felstones. They occur singly and in groups. The best instances of the latter arrangement may be seen on Culvennan Fell and Barskeoch Fell, and round Dowalton Loch, near Sorbie. The felstones are for the most part composed of a grey, pink or purple, orthoclase base, with a few crystals of hornblende, quartz, and mica. A good instance of this typical felstone occurs as a large mass near Kirk of Mochrum towards the southern margin of the Sheet. Sometimes crystals of plagioclase felspar are abundantly scattered through the rock. Crystals or threads of talc often abound in the felstone dykes, which cut through the cliffs on the west side of Wigtown Bay, as, for example, at Innerwell Point. Some of the dykes in Culvennan Fell also contain talc, and in one of these numerous needle-shaped crystals of apatite may be observed. Hornblende is very abundant in a dyke a little to the west of the felstone mass near Mochrum, so much so that in places the rock passes into a syenite.

Drift.

40. The whole area embraced in this Sheet presents undoubted proofs of the general glaciation to which the country has been subjected. These will be described in the following order:—1st, Striated Rock Surfaces; 2d, Till or Boulder Clay; 3d, Sands and Gravels; 4th, Erratic Blocks; 5th, Brick Clays; 6th, Moraines.

STRIATED ROCK SURFACES.

41. Evidences of the passage of ice over the land abound in the form of rounded hills and smoothed hummocks of rock. These become especially prominent among the low hills of Wigtownshire, where good instances of bare *roches moutonnées* everywhere present themselves, and form a striking and very characteristic feature in the landscape. In most cases, the rock surfaces having been long exposed to the weather, the fine markings have been obliterated, but where the rock has been newly laid bare, its smoothed and polished face may be seen to be covered with grooves and fine striæ. Good examples of this kind occur round the shores of Mochrum and Castle Lochs, south of Kirkcowan, and along the line of the Wigtownshire Railway west of Newton-Stewart. In the Kirkcudbrightshire portion of the Sheet, though the hills still present the same generally rounded appearance, the finer grooves and striæ are less frequently visible, owing doubtless to the more decomposable surfaces of the granite and schists which there prevail. Only where a fresh exposure of these rocks has been made can the striæ be observed upon them. The localities where striated rock surfaces have been observed are marked by a particular sign on the Map. It will be seen from these indications that the general trend of the ice-flow was from the high ground north of this Sheet, in a south and south-west direction into the Irish Channel.

A mass of ice can thus be shown to have descended the valley of the Cree, nearly as far as the town of Wigtown, where it must have met the ice shed off towards the south-west from the high ground of Cairnsmore. The united stream would then move towards the south and south-west, which is the direction indicated by the striæ below Wigtown. A fuller account of the ice movements in this district will be given in the Explanation to Sheet 8, lying to the north of the present Map, and including all the high ground from which the ice moved.

BOULDER CLAYS.

42. These deposits present the usual character of tough clay, quite unstratified and full of smoothed and striated stones of various sizes. Sometimes scratched boulders are found up to 3 and 4 feet in diameter, but these are of rare occurrence. The general colour of the clay is grey and bluish-grey, but along the south edge of the Sheet it has a brownish and yellow tinge, due to the red ferruginous colour of the underlying Ardwell rocks.

An examination of the stones in the boulder clay confirms the evidence given by the striæ as to the direction of the ice flow. The more oblong boulders are generally found with their longer axes pointing in the same direction as the scratches. Numerous granite stones from the Cairnsmore mass appear in the till covering the low ground of Wigtownshire, and fragments of some of the best-marked dykes and intrusive masses along the north edge of the Sheet likewise occur in the drift to the south-west. East of the river Cree, and north of the line of railway from Newton-Stewart to the west edge of the Sheet, the boulder clay occurs in undulating slopes along the hill-sides, and in rudely marked terraces along some of the larger watercourses. This latter arrangement is well seen up the Moneypool Burn north of Creetown, where the stream has cut its channel through the drift, exposing sections fully 30 feet in depth. Over most of the Wigtownshire area the boulder clay occurs in the form of smooth rounded hills or "drums." Well-developed examples vary the ground between Glenluce and Kirkcowan, and also round Wigtown, Kirkinner, and Sorbie. These generally run in parallel but independent ridges; sometimes they are clustered together in groups of from four to six connected mounds. They vary in height from 40 or 50 up to 150 feet. As a rule the base of their slopes forms a sharp and well-defined line with the ground from which they rise. In the north-west parts of the district the drums are generally surrounded by large flat peat mosses, while in other places they rise from bare rocky ground sparsely covered with heath or grass. In few cases do they stand up out of smooth sheets of boulder clay. It is evident, from an examination of these drums, that their peculiar form and position are due to original deposition, and not to subsequent denudation. This is apparent—1st, from their occurrence chiefly on the low grounds, otherwise nearly bare of drift—a solitary drum being often found on an open plain of bare rock or peat; 2d, from the sharply defined limit of their base; and 3d, from the fact that on the whole the longer axis of the mounds corresponds with the general direction of the glacial striæ in the district. Small patches of sand and gravel sometimes appear in the boulder clay, but they are of rare occurrence and of small extent.

SANDS AND GRAVELS.

43. This series is poorly represented in the present Sheet. A few small kames occur, scattered singly or in groups over the moorlands of Wigtownshire, and gravel deposits are seen along the valleys of the Cree and Bladenoch; but on the low ground in the south half of the Sheet such accumulations are almost entirely wanting. Small patches of them are seen along the shores of Luce Bay, and at the head of Wigtown Bay, most probably fragments of greatly denuded old sea-beaches. The best development of kames lies about 5 miles north-west of Kirkcowan from Loch Ronald across the watershed between the Tarf and Bladenoch to

Ballochadee. The greatest height at which they occur is about 350 feet above the sea-level. Some good examples of gravel mounds also appear about Mark of Shennanton and Bladenoch Bridge, north of Kirkcowan. Considerable deposits of gravel cover portions of the valley of the Cree north of Newton-Stewart. These are well seen on either side of the river at Boreland and Challoch, where they strew the valley for the breadth of half a mile, forming small hillocks and rolling ground, with here and there fragments of terraces. At Challoch Bridge a fine section of stratified sand and gravel is exposed to a depth of 40 feet.

ERRATICS.

44. Boulders of Cairnsmore granite are found plentifully scattered over the low ground of Wigtownshire and the Kirkcudbrightshire hills south of Cairnsmore of Fleet. They occur in all positions, lying on drums and flats of boulder clay, on bare rocky moors, and on and partly embedded in peat mosses. Boulders of greywacke, grit, and fine conglomerate are also very numerous, the latter being often recognisable as belonging to some of the well-marked pebbly bands in the north-west of the Sheet. Large diorite boulders are scattered over the low grounds towards the west.

BRICK CLAYS.

45. This series, as represented in the present Sheet, is not a glacial deposit, but forms part of the 25-feet raised beach, and is well developed on both sides of the river Cree south of Newton-Stewart. It consists of a set of finely laminated brown and bluish clays, containing very few stones, and those very small, with here and there beds of fine gravel. These clays have been worked at Carty Bridge, about half a mile south of the Cree Railway viaduct, where sections of from 10 to 15 feet deep are exposed. No organic remains have been found in them.

MORAINES.

46. Moraines are very poorly represented in this Map, where they only form the edge of a large series extending northward over Sheet 8, in the Explanation to which they will be fully described. The high ground round Cairnsmore of Fleet nourished a set of small local glaciers towards the end of the glacial period, traces of which are seen in all the surrounding valleys, commonly in the form of smooth slopes of loose stony and sandy moraine drift on either side of the burn-courses. Sometimes the ordinary stiff boulder clay is exposed below the Moraine matter, as may be well seen up the Graddoch Burn, east of Cairnsmore House.

A few groups of well-marked moraine mounds are also seen in this district. Good examples occur on the moor north of the railway between Creetown Station and Culcronchie viaduct. Some of these mounds are 100 yards long and 30 to 40 feet high. Where sections are exposed in that neighbourhood, the material of the moraines is seen to be very gravelly, the stones being as a rule fine and rounded. In places there are quantities of sand mixed up with the gravel. The stones are for the most part of granite. Much the most marked moraine mounds in this Sheet, however, occur on Cullendoch Moor, near the sources of the Big Water of Fleet, and along the line of railway between the Fleet viaduct and Drumore station. In the former locality the mounds lie scattered over the flat moss on each side of the Fleet, small groups lying opposite the mouths of the larger valleys which come down from the east side of Cairnsmore, and south from the hills enclosing Lochs Grennoch and Fleet. The drift where exposed is very loose, sandy, and gravelly, the stones being rounded or subangular. They are mostly of granite, but a very few striated subangular fragments of schist have been noticed. Between Dromore station and the Water of Fleet a group of small conical moraine mounds can be well seen from the railway. They are of the same sandy, gravelly material as those to the north. Farther down the Fleet valley the moraine matter is spread out in slopes over boulder clay, and merges into the latter so gradually that it is impossible to draw a sharp line between the two.

LOCHS.

47. The water-basins in the present Map may be described in this place, seeing that there is reason to believe them all to belong to the glacial period. They are only nine or ten in number, none being of any great size. The largest, Loch Grennoch, in the north-east corner of the Sheet, is 2 miles long by less than half a mile broad. This is a true rock-basin due to glacial erosion. Occupying a narrow valley between the steep hills of Craigeazle and Craigwhinnie, it presents, round its shores and on its islets, smoothed ice-worn rock-surfaces on which in several places striæ may be observed running parallel to the length of the loch. Loch Fleet, lying about 1 mile east of Loch Grennoch, is another instance of a rock-basin. The two most important lochs in Wigtownshire, Castle Loch and Mochrum Loch, about 5 miles south of Kirkcowan, both in this Map, are likewise good examples of rock-basins. Their marginal rocks exhibit admirably the effects of glaciation. The whole of the islands which dot their surfaces are smoothed and striated from end to end. The rest of the lochs lie in hollows of the drift, or occupy depressions in some of the large flat peat mosses. Loch Ronald may be taken as a good example of the former structure. It is dammed up by a large kame of sand and gravel, through which the water has cut a narrow channel. A remarkable example of the union of ice-worn rock-surfaces with surrounding ramparts of drift is afforded by Dowalton Loch, near Sorbie. By draining operations this former sheet of water has been removed, and its bottom can now be examined. Flat sheets and low ridges of well-smoothed and striated rock rise from under the alluvial deposits of the old lake, up to the bases of the encircling "drums" of boulder clay. The Black Loch, near Drumwalt in Mochrum parish, and Dernaglar Loch, between Glenluce and Kirkcowan, may serve as instances of lakes surrounded by peat mosses. In these cases it may be supposed that the sheets of water once covered the area occupied by the peat mosses, and that they have gradually diminished in proportion as the peat has encroached upon them.

Raised Beaches.

48. Along the shore of Luce Bay, from Auchenmalg to the south edge of the Sheet, a narrow shelf of shingly gravel extends inland from the present beach for 50 to 100 yards; and marks the most recent of the raised beaches in this district. It lies 25 feet above the present high water level, and terminates along its inner edge at the base of a line of steep grassy bank. This marginal escarpment consists for the most part of boulder clay, but at Chippermore it presents for fully a mile a face of rock from 30 to 40 feet high, along the base of which the effects of old sea-action are still plainly visible. The rocks are smoothed

and rounded, and have here and there been hollowed out into shallow caves. In course of time the terrace has been greatly destroyed by denudation; but considerable fragments of it may still be seen along the east side of Wigtown Bay, wherever breaches occur in the line of cliffs, as at Garlieston Bay, at Orcharton, and Baldoon. Along the north side of the same bay from Creetown to Ravenshall it forms a strip of flat ground between high-water mark and an inner line of old sea-cliff. The largest and most perfectly preserved portions of this beach, however, are seen on either side the Cree from Wigtown sands to Machermore, in the form of broad flats. Those on the south side of the river are mostly covered by peat mosses, which near the water give place to a belt of rich arable land. The terrace consists here of stiff clay, often finely laminated with occasional thin bands of gravel and beds of sand. (See par. 45). Along the inner margin it slopes up into a higher, and perhaps to a large extent fluviatile or estuarine terrace, fragments of which are well preserved at Clary on the south side of the river and at Calgow on the north side. This upper and older platform has here a height of about 50 feet above high-water mark. It extends in a broad grassy flat, from Calgow northwards, gradually rising in level as it proceeds, till at the Cree Bridge at Newton-Stewart it has reached a height of from 60 to 70 feet. Fragments of the same terrace are also seen at Machermore sloping up to a height of 75 and 80 feet. There may indeed be here a 75-foot terrace, but its remains are too fragmentary to be mapped out separately in this district. Sections of the second terrace are exposed at Machermore and Calgow. It consists of stratified sands and well-rounded gravel. No organic remains have been found in any of the terraces in this Sheet.

Alluvium and Peat.

49. The alluvial deposits are here of but limited extent. They lie in the chief river valleys and along some of the burn-courses in the low grounds of Wigtownshire. A considerable extent of marine alluvium occurs at the head of Wigtown Bay, on either side of the mouths of the Cree and Bladenoch. It consists of large flats of mud and shingle, laid bare at low tide. The whole of Fleet Bay is also occupied by a more sandy marine alluvium, likewise exposed on the recession of the tide. The principal areas of fresh water alluvium lie along the course of the river Bladenoch, where it forms considerable flats, as at Dalreagle, Grange and Shennanton. The Waters of Tarf, Cree, and Palnure are also bounded here and there by level alluvial plains. As already mentioned (par. 47), a considerable extent of alluvium has been laid bare by draining at Dowalton Loch, in the low grounds of Wigtownshire, since the present Sheet of the Ordnance Map was surveyed. Besides the higher terraces at the mouth of the Cree, which as already suggested may be partly fluviatile or estuarine and partly marine, fragments of older river terraces may be seen flanking the lower and more recent alluvium of several of the rivers. At the junction of the Tarf and Bladenoch below Kirkcowan, portions of two such higher terraces rise above the existing river flats. Other examples occur at Mark of Shennanton on the Bladenoch, near Barnernie on the Tarf, and at other localities marked on the Map.

50. The hilly ground in this Sheet is for the most part covered with turf and peat. On the higher hills and steep slopes this only forms a thin covering, but in some of the hollows among the hills the peat deepens and forms large flat mosses. The best example is Kilquhockadale moss, which covers more than 2 square miles, and is fully 14 feet thick in some places. The largest peat mosses, however, occur on the low

grounds between Glenluce and Kirkcowan, where several heath-covered flats of peat, all joined with one another, together cover an area of 6 or 7 square miles, as shown on the Map. Other large mosses fill up hollows between "drums" of boulder clay, near Eldrig and Mochrum. As has been already mentioned, large accumulations of peat lie on the 25-feet raised beach at the mouth of the Cree. The most extensive of these, called the Moss of Cree, covers 1½ square miles, and has a depth of 18 to 20 feet in places. On the north side of the river the peat has been removed from large tracts of the terrace, and the ground is now under cultivation. The peat in this neighbourhood has yielded quantities of bog-oak of sufficient size and firm quality to be used for furniture, ornaments, &c. Traces of roots and bark of fir, alder, and birch are common in all the peat mosses of the district.

V. ECONOMIC MINERALS.

51. *Building Stones.*—Several quarries have been opened and largely worked in the Silurian rocks of this area. They are all confined to the Queensberry grit group, which of all the Silurian subdivisions forms, from its regular system of joints and even bedding, by far the best materials for building purposes. The largest quarries have been opened near Glenluce, where some of the higher beds of the group are worked for pavements, lintels, &c. Other quarries near Newton-Stewart and Wigtown have been largely worked of late for stones to build bridges and other works connected with the new Wigtownshire Railway. Much the most important building stones in this Sheet, however, are obtained from the areas of fine-grained granite south of Creetown. From the quarries there, which have been worked for a great number of years, stones are exported to various English and Scotch ports. The quarries at Kirkmabreck Manse, near Creetown, often give employment to 400 men. The new docks at Liverpool have been entirely built of stones from this granite. The Cairnsmore granite has only been used to a small extent for building. Some houses in Newton-Stewart have, however, been built of it, the stones being brought from quarries near Craigdews, at the extreme north edge of the Sheet.

52. *Road Metal.*—The greywacke beds are often used for road metal, and some of the hard tough Queensberry rocks serve very well for this purpose. The strata belonging to the other Silurian groups are as a rule too shattery and jointed to be of much value. Some of the felstone dykes are also largely employed for road metal, for which they are well adapted on account of their toughness and durability.

53. *Brick Clays.*—A series of tough reddish and brown clays, forming part of the 25-feet beach, is worked near Carty, 2 miles south of Newton-Stewart, for the manufacture of bricks and tiles. The same deposit occurs extensively there on both sides of the river Cree.

54. *Ores.*—Galena has long been worked at several localities in this Sheet. The most important of these is Blackcraig, near Newton-Stewart, where large mines have been opened in the Lower black shale and lower part of the Queensberry group. The galena is here associated with zinc blende, and occurs in veins which, as shown upon this Map, have a general trend from E.S.E. to W.N.W. A few transverse veins run generally N.N.E. The galena being slightly argentiferous, small quantities of silver are obtained from it. The same ore of lead has been mined in considerable quantities in the Wood of Cree, opposite Penninghame House; at the Cairnsmore mines, near Cairnsmore House; and at the Pibble Hill mines, east of Creetown; but these three workings,

proving unremunerative of late years, are now shut up. The veins worked at Cairnsmore were a continuation of these in the Blackcraig mines. The galena occurred in veins and "pockets" generally mixed up with quartz and calcite.

55. *Copper pyrites* occurs in thin veins here and there among the Queensberry grits, but not in sufficient quantity to remunerate the working. A vein was mined for a short time at Wauk Mill, near Kirkcowan, but it has now been abandoned.

56. *Fuel.*—Peat is the only fuel which occurs in this Sheet, and it is largely used all over the district.

APPENDIX TO SHEET 4.

I.—LIST OF LOCALITIES

FROM WHICH FOSSILS HAVE BEEN COLLECTED BY THE GEOLOGICAL SURVEY IN EAST WIGTOWN AND SOUTH-WEST KIRKCUDBRIGHTSHIRE.

Collector—Mr A. Macconochie.

(*The numbers are those by which the localities are denoted in the succeeding List of Fossils.*)

LOCALITIES IN SHEET 4.

A. Newton-Stewart and Kirkcowan Districts.

1. River Cree, bend opposite Knockstocks, 1 mile N. of Newton-Stewart.
2. The same—few yards further down the river.
3. Penkill Burn, opposite Glenhoise, 2 miles N. of Newton-Stewart (indication of Graptolites).
4. Hillside at Loch of the Lowes, 5 miles N. by E. of do. (indication of Graptolites).
5. Roadside, Wood of Cree, 4 miles N. by W. of do.
6. Roadside at Garwachie, 6 miles W. by N. of do.
7. Glassock (N. of), 6½ miles N.N.W. of do.
8. Head of Burn, 1½ miles N. of Glassock.
9. Near the Snap, 7 miles W.N.W. of Newton-Stewart.
10. Roadside, N. of Carseriggan, 5 miles N. of Kirkcowan.
11. Roadside, W. of Balminnoch, 5 miles N. by W. of do.
12. Burn at Drumabrennan, 4½ miles N. by W. of do.
13. Tarf Water, Wauk Mill, at Kirkcowan.

B. Glenluce District.

14. Hillside, N.-E of Ringdown, 3 miles N. by E. of Glenluce.
15. Burn, E. of Camrie, 2½ miles N. of do.
16. Drumpail Burn, opposite Drumpail, 3 miles N. of do.
17. Shore, opposite Castle Sinniness, S. of Glenluce.
18. Shore, near Low Sinniness.
19. Cliffs, opposite Sinniness.
20. Gillespie Burn, opposite Culroy, 4 miles E.S.E. of Glenluce.
21. Roadside, N. of Barhaskine, 4½ miles E.S.E. of do.
22. Black Loch, about 6 miles E. of Glenluce.

C. District of Kirk of Mochrum.

23. Old roadside, S.W. end of Eldrig Loch, about 2½ miles N.W. of Kirk of Mochrum.
24. Loch Head, Eldrig Loch.
25. Crailloch, N. of Low Glenling, about 3½ miles N. of Kirk of Mochrum.
26. Burn, W.N.W. of Low Glenling.

D. Wigtown District.

27. Railway Cutting at Bladenoch, S. of Wigtown.
28. North side of Garliestown Bay, 6 miles S. by E. of do.
29. Railway Cutting, N. of Whaup Hill, 4 miles S. by W. of do.

LOCALITIES IN SHEET 2.

(Addional to those given in the Appendix to the Explanation of that Sheet.)

Isle of Whithorn and Burrowhead Districts.

30. Steinhead, N. of Isle of Whithorn (inorganic markings ?).
31. Shore, 2 miles S. of do.
32. Shore, cliffs S. of Morrach, about 2 miles S. of do.
33. Shore, cliffs between Broom Point and the Devil's Bridge, Burrowhead.
34. Shore, close to the Devil's Bridge, Burrowhead.
35. Shore, higher up the cliffs.
36. Shore, a few yards S. of the Devil's Bridge.
37. Shore, at water-mark, do.
38. Shore, cliffs E. of Fort, Burrowhead.
39. Burrowhead, extreme point of head.
40. Small pond in field, N. side of Burrowhead.
41. Shore, a little W. of Burrowhead.
42. Cliffs, W. side of do.
43. Cliffs, W. side of Fort, at Burrowhead.
44. Base of Cliff, W. side of do.
45. Shore, 150 yards W. of Fort, do.
46. Shore, near Castle Feather, do.

II.—LIST OF SPECIES.

Lower Silurian.

Ardwell Group (Thin Fissile Shale).

Class, etc.	Name.	Locality Number.
	Inorganic markings (plume-like),	28.
Hydrozoa ?	Protovirgularia.—*Sp.*	28.

Lower Black Shale.

Graptolitidæ,	Climacograptus bicornis.—*Hall,*	26.
	,, teretiusculus.—*His,*	25, 26.
	,, *Sp.*	2, 22.
	Cœnograptus gracilis.—*Hall,*	26.
	Corynoides calicularis.—*Nicholson,*	26.
	Dawsonia campanulata, ,,	1.
	Dicellograptus anceps, ,,	2, 26.
	,, *Sp.*	20.
	Dicranograptus Nicholsoni.—*Hopk.*	26.
	,, *Sp.*	26.
	Diplograptus bimucronatus.—*Nich.*	26.
	,, acuminatus, ,,	22, 24?, 25.
	,, pristis.—*His,*	2, 20, 21?, 26.
	,, *Sp.*	2.
	Graptolithus (large sp.),	2.
	Pleurograptus linearis.—*Carr ?*	25.
	Thamnograptus (n. sp.?),	26.

Queensberry Group.

Indications of Graptolites,	13.

Haggis-rock (Fine Conglomerate).

Class, etc.	Name.	Locality Number.
Actinozoa,	Heliolites ? (fragment),	8.
	Petraia.—*Sp.* (fragment),	8, 9.
Echinodermata,	Crinoid stems (fragmentary casts),	8.
Polyzoa,	Ptilodictya.—*Sp.* (fragment),	9.

Upper Black Shale.

Graptolitidæ,	Climacograptus bicornis.—*Hall,*	6, 7, 10, 15.
	,, teretiusculus.—*His,*	5, 11, 15.
	,, *Sp ?*	5, 10, 11, 12, 14, 15, 16.
	Dawsonia campanulata.—*Nich.*	5, 10, 15, 16.
	Diplograptus pristis.—*His,*	5, 6, 10, 11, 12, 15, 16.
	,, tricornis.—*Carr. ?*	10.
	,, *Sp.*	5, 14, 15.
	Corynoides calicularis.—*Nicholson ?*	10, 15.
	Dicellograptus.—*Sp.*	5, 11.
	Dicranograptus ramosus.—*Hall,*	14.
	,, *Sp.*	10.
	Retiolites latus.—*Nicholson,*	5, 11.

Dark Blue Shale.

Graptolitidæ,	Diplograptus folium, *His,* or D. palmeus, *Barr* (fragment),	29.
	Graptolithus Clingani.—*Carr.?*	29.
	,, lobiferus.—*M'Coy,*	27?, 29.
	,, Sedgwickii.—*Portlock,*	27?, 29.
Crustacea,	Discinocaris or Peltocaris.—*Sp.* (fragment of Carapace),	29.

Upper Silurian.

Shale.

Graptolitidæ,	Cyrtograptus Murchisoni.—*Carr* (or n. sp.?),	31, 33, 34 ?. 35, 36, 39?.
	Cyrtograptus (C. Carruthersi.—*Lapworth,* or n. sp.?),	38 ?
	Graptolithus Flemingii.—*Salter ?*	38, 44.
	,, priodon.—*Bronn,*	31, 34, 35, 39,
	,, vomerinus.—*Nicholson ?*	31, 33, 34, 35, 36, 37, 39, 40, 41, 43.
	Retiolites Geinitzianus.—*Barr* (or n. sp.?),	33, 34, 35, 36, 39, 41, 45.
Actinozoa,	Heliolites ?—*Sp.* (cast),	35.
Echinodermata,	Crinoid stems (small casts),	33, 35.
Crustacea,	Ceratiocaris ?—*Sp.* (abdominal segments and tail species),	46.
Cephalopoda,	Orthoceras.—*Sp.* (fragments),	31, 34, 35, 36 ?, 40 ?, 41, 43.

N.B.—We are indebted to Professor H. A. Nicholson, M.D., &c., for assistance in the determination of some of the more obscure Graptolites.

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SCOTLAND.

EXPLANATION OF SHEET

5

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By JOHN HORNE, F.R.S.E.,
With the Collaboration of B. N. PEACH, F.R.S.,
and J. J. H. TEALL, F.R.S.

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PREFACE.

THE Map to which the following pages are intended to serve as an Explanation embraces a large part of the county of Kirkcudbright, extending along the coast from the mouth of the Fleet to near Southerness, and thence inland to a line drawn from the granite hills above Loch Skerrow eastwards to the alluvial plain of the River Nith, near Kirkconnel.

The ground contained within these limits has already been more or less fully examined and described by various geologists. Hay Cunningham, as far back as the year 1843, gave a luminous sketch of the general geological features of the county of Kirkcudbright. Harkness studied the sections of the coast-line and recorded the Upper Silurian fossils found there by himself; while his lists were subsequently increased from the determination by Salter of further specimens collected by Fleming and Underwood. The full titles of the papers by these observers will be found in the Appendix (C), and references are given in the text to some of the more important results obtained.

The area in question was mapped for the Geological Survey, under my supervision, by Messrs John Horne, D. R. Irvine, and C. R. Campbell. Mr Irvine's area extends from Gatehouse-of-Fleet to Lawrieston, and amounts to about 40 square miles. Mr Campbell's share was a narrow strip along the northern margin of the Map from Parton Station to Killywhan; the rest of the district was mapped by Mr Horne.

The Map thus geologically surveyed was published as far back as the year 1879. The appearance, however, of Professor Lapworth's Memoir on "The Moffat Series," in 1878, to which more detailed reference is made in the following pages, rendered it desirable to delay the issue of an explanatory Memoir of the Map until the ground could be again traversed in the light of his researches, which had at last supplied, in the zonal distribution of the Graptolites, a clue to the unravelling of the complicated structure of the Southern Uplands. Accordingly, as the exigencies of other departments of the work of the Geological Survey would permit, the whole region of these uplands has gradually been revised, more especially with reference to the occurrence and stratigraphical position of the bands of graptolitic black shale. This revision has been accomplished by Mr Peach and Mr Horne, with the assistance of Mr A. Macconochie, and has resulted in the discovery of several new and interesting features in the Silurian Geology of the South of Scotland. The last part of the revision of the present Map was completed only in the autumn of this year, when the Granite areas, with their network of dykes and aureole of metamorphism, were re-examined by Messrs Peach, Horne, and J. J. H. Teall, accompanied during part of the time by myself.

The following Explanation has been mainly written by Mr Horne, in constant consultation with Mr Peach. The descriptions of the Black Shale bands in the Llandovery area are based on the joint surveys made by them, with Mr A. Macconochie's assistance. The Petrographical part of the Appendix (A), and the descriptions of the microscopic structures of rocks cited in the text, have been supplied by Mr Teall. The Lists of Fossils have been furnished by Mr Peach, who has also prepared the Palæontological section of the Appendix (B), Professor Lapworth kindly contributing his valuable aid.

There are several features of geological interest in this Memoir to which special attention may be directed here. While the existence of volcanic rocks at Ballantrae was ascertained many years ago by Professor Bonney, and their Arenig age was subsequently fixed by Professor Lapworth, Mr Peach, in the year 1888, during the course of the revision of the Southern Uplands, made the important discovery, that in the central parts of that region the lowest visible portions of the Silurian Series are volcanic rocks,—lavas, tuffs, and agglomerates. As a rule these masses are only seen on the narrow crests of anticlinal folds, but we have traced them to the south-west by Sanquhar and Ballantrae to Glenluce. This volcanic series descends into the Arenig group, and in some places rises even into the Bala group. It is not well developed in the present district, but may be seen in the northern part.

Another fact of great consequence was ascertained for the first time during the revision: the occurrence of a well-marked and persistent horizon of Radiolarian cherts and mudstones intercalated in the upper portion of the Arenig division of the volcanic series just referred to. From the distinctive lithological characters of this band of strata, it forms an exceedingly useful platform in the unravelling of the plicated structure of the region. A further point of much interest in connection with the stratigraphical position of these cherts is found in the fact, that while the graptolites in a black shale at the base of the cherts belong to the middle division of the Arenig group, those that occur in the black shales immediately overlying the cherts are forms distinctive of the uppermost Llandeilo strata. It would thus appear that these cherts, although only about 60 or 70 feet thick, represent the whole succession of deposits which elsewhere in Britain intervene between the Middle Arenig and uppermost Llandeilo strata. They seem to indicate a long interval during which the sea-floor, where they were laid down, remained nearly free from the deposition of ordinary sediment. The zone of cherts is well shown in the district described in the present Explanation. Although Arenig fossils have not been met with here, the strata which we have recently found near Leadhills to yield *Tetragraptus*, a characteristic Arenig graptolite, undoubtedly come up with the cherts at Trowdale Glen in this district. We are thus able by palæontological, stratigraphical, and lithological evidence to establish that Arenig rocks extend far beyond the limits within which they have hitherto been known to occur at Ballantrae.

In studying the complex series of granites, quartz-diorites, porphyrites, etc., which traverse the Silurian formations, we have obtained some interesting examples of a foliated structure along some parts of the margin of the Criffel granite, and, at the same time, evidence that this structure has been produced by mechanical deformation which has simultaneously affected not only the main body of the granite, but also the basic inclusions which this rock contains, as well as the acid veins that traverse it.

While tracing the glaciation of the region, Mr Horne obtained proofs that the ice which drained from the inland country was in mass sufficient to override Criffel, and must therefore have had there a minimum thickness of 2000 feet. This is a fact of much interest in view of the wide distribution of boulders of the Criffel granite over the North of England and even as far south as Wales.

ARCH. GEIKIE,
Director-General.

GEOLOGICAL SURVEY OFFICE,
28 JERMYN STREET, LONDON,
19*th December* 1895.

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EXPLANATION OF SHEET 5.

I. AREA EMBRACED IN THE MAP.

The district represented in the present sheet of the Geological Survey Map of Scotland embraces an area of 343 square miles, forming the south-eastern portion of the county of Kirkcudbright. Bounded on the south by the Solway Firth and the Irish Sea, it extends from Gatehouse-of-Fleet on the west to Criffel on the east. Its northern margin is defined by a line drawn from Loch Arthur by the village of Kirkpatrick-Durham to Loch Skerrow in the north-west corner of the Map. It thus includes the lower portions of the basins of the Fleet, the Dee, and the Urr, the prominent mass of high ground round Criffel, Screel, and Bengairn, and the pastoral tracts stretching northwards from the Twynholm Hills to Loch Skerrow.

A narrow strip of ground, about 17 square miles in extent, along the western border of the adjoining Sheet 6, is also described in the following pages. Stretching from Southerness by the village of Kirkbean to Kirkconnell Moss on the banks of the Nith, this tract is likewise included in the county of Kirkcudbright. As it contains a portion of the eastern margin of the granitic mass of Criffel with Silurian and younger Palæozoic strata which are continued westwards into Sheet 5, it may be more conveniently described with the latter map.

II. FORM OF THE GROUND.

The most elevated tract of ground is situated in the eastern part of the area. It extends from Criffel (1866 feet), the highest elevation in the Map, north-west by the Cuil Hill, and the Long Fell to the Lotus Hill (1050 feet), south of Killywhan Station. This chain of heights forms an important watershed, as the streams to the north and east of this line drain into the Nith, while those to the west and south-west flow partly into the Kirkgunzeon Lane, a tributary of the Urr, and partly into the Solway Firth near Southwick. Between this water-parting and the valley of the Urr, south of Dalbeattie, there is a succession of heathery hills and granite ridges, gradually decreasing in height towards the alluvial plain of the Urr. The prevalent trend of these ridges is N.N.W. and S.S.E., and their height between Dalbeattie and Colvend varies from 200 to 400 feet. The alluvial plain at Dalbeattie is flanked on the west by a ridge of hills rising to a height of 500 feet above the level of the plain at their base. Towards the centre of the area there is a prominent mass of high ground, of which the highest elevations are Bengairn (1280 feet) and Screel (1100 feet), forming striking features in the southern part of the county. Indeed, the eastern slope of Screel rises to a height of 1000 feet above the level of the raised beach at its base. Again, in the pastoral tract, towards the north-west portion of the Map, between the Twynholm Hills and Loch Skerrow, the ground is everywhere hilly, some of the heights ranging from 1000 feet to 1200 feet.

The remaining portions of the district form a gently undulating tract of low ground which, for the most part brought under cultivation, stretches from the mouth of the Fleet eastwards to Auchencairn, northwards by the valley of the Dee to Parton, and eastwards by Castle-Douglas and Kirkpatrick-Durham to the northern slopes of the granite hills at Killywhan.

Some of the foregoing physical features furnish excellent examples of the relation which exists between geological structure and external forms of the ground. The rugged hills, crags, and knolls strewn with boulders, extending from Criffel to Bengairn, are due to the great mass of igneous rocks occupying that area. The picturesque escarpment rising from the alluvial plain at Dalbeattie is formed mainly of a belt of altered Silurian strata in contact with the granite. In like manner, the rocky cliffs on the southern slope of Screel are composed of hardened Silurian rocks, traversed by numerous dykes of igneous material, connected with the granite. The general influence of denudation in producing inequalities of the surface is further shown by a marked rib-shaped contour in the tracts of cultivated ground within the Silurian area. Where the superficial deposits are comparatively thin, these rocky features trend in a north-east and south-west direction in harmony with the strike of the strata. In these instances the harder greywacke bands protrude, while the softer flags and shales have been worn into hollows now partly filled with drift. These features are well expressed by the shading on the Map in the area between Gatehouse-of-Fleet and Kirkcudbright.

Apart from the operation of denuding agencies now at work in modifying the surface of the region, there is abundant evidence to show that many of the ridges and hollows have been produced or modified by ice-action during the glacial period. The rocky ridges between Southwick and Dalbeattie, trending in a S.S.E. direction, are doubtless largely due to the operation of land-ice moving towards the Solway Firth. But to the north-west of the granite area, particularly in the region to the north and west of Castle-Douglas, these features are caused by the arrangement of the drift deposits. It will be shown, on a subsequent page, that the boulder clay has there been accumulated in the form of ridges, the trend of which generally coincides with that of the ice-striæ on the rocks.

In these various instances, the natural features have been produced by geological agencies irrespective of the existence of faults. There is one prominent feature, however, in the region which is due to a fault. The rocky coast line between Southwick and the mouth of the Urr—a distance of 6 miles—has been determined by a line of displacement skirting the base of the cliff, and bringing Lower Carboniferous strata in contact with Silurian rocks altered by the granite.

As already mentioned, the main lines of drainage are those of the Fleet, the Dee, and the Urr, of which the Dee is the most important. Entering the Map at Loch Stroan, the Dee unites with the Ken near Parton, and flows in a S.S.E. direction, with a slight fall to the Bridge of Threave. Here it enters a rocky gorge, which is nearly continuous as far as Tongueland, whence it winds through alluvial flats to the sea. The Urr enters the Sheet near the village of Kirkpatrick-Durham, and for some miles flows through richly cultivated ground. At Dalbeattie it has nearly reached its base-level of erosion, and from that point, for a distance of several miles, it intersects the granite area in its course to the sea. These rivers are examples of the transverse system of valleys, while some of their tributaries illustrate the longitudinal system. Further evidence might be adduced of the formation of transverse hollows by the erosive action of streams of which there are several examples between the Urr and the Nith. In the north-east corner of the district, the New Abbey Burn rises within a short distance of the northern boundary of the granite mass, and traverses the granite area for several miles in its course to join the Nith. By the recession of two streams flowing in opposite directions —one north by the Edingham Moss to the Kirkgunzeon Lane, and the other south to Sandyhills Bay—the granite tract has been intersected by a prominent transverse hollow.

There are several sheets of water within the area, notably, Loch Skerrow, Woodhall Loch, Loch Whinyeon, and Loch Kinder. Some of the lochs are due to the irregular distribution of the superficial deposits, others have probably been eroded in part by ice-action.

III. FORMATIONS AND GROUPS OF ROCK.

Aqueous.

	Recent and Post-Tertiary.	Blown Sand. Peat. Alluvium of River Terraces and Old Lakes. Recent Marine Mud and Sands. Raised Beaches.
	Drift Series.	Moraines. Erratic Blocks. Sands and Gravels. Boulder Clays. Ice-worn Rock Surfaces with Striæ.
Carboniferous.	Calciferous Sandstone Series.	Coralline Limestones of Arbigland. Sandstones, Shales, and thin Marine Limestones. Thirlstane Sandstones. Sandstones, Shales, with Marine Bands. Sandstones, Shales, and Cement-stones, resting on contemporaneous Volcanic Rocks.
	Upper Old Red Sandstone.	Red Sandstones, Grits, and Marls.
Silurian.	Ludlow and Wenlock.	Shales, with Limestone nodules, Flags, and fossiliferous Conglomerates. Grey sandy Grits, Greywackes, Flags, and Shales, with Graptolite bands.
	Llandovery.	Brown Crusted Greywackes, Flags, and Shales. (Hawick Beds.) Massive Grits, Greywackes, and Shales. (Queensberry Grits.) Flags and Shales, with occasional Greywackes. Black Shales, alternating with grey shales in the higher zones. (Birkhill Shales.)
	Caradoc.	Shales and Mudstones. (Barren Mudstones.) Black Shales. (Hartfell Shales.)
	Llandeilo and Arenig.	Black Shales. (Glenkiln Shales.) Radiolarian Cherts, Mudstones, and Shales, associated with fine Volcanic Tuffs.

Metamorphic.

Hardened Silurian Greywackes, usually of a brown tint, from the presence of minute biotite.

Fine-grained Mica-schists and Gneissose Rocks (Silurian).

Igneous.

I. Inter-bedded or contemporaneous with the formations in which they occur.
   Andesites, etc.

II. Intrusive or later in date than the formations in which they occur.
   a. Rocks forming the large Granite Masses :—
      Muscovite - biotite - granite, Biotite - granite, Hornblende-biotite-granite, Quartz-diorite, &c., massive and foliated.
   b. Rocks occurring for the most part as Dykes :—
      1. Porphyrites.
      2. Diorites.
      3. Mica-traps.
      4. Basalt Rocks of doubtful age.
      5. Andesite in Volcanic 'Necks.'

IV. GEOLOGICAL STRUCTURE OF THE DISTRICTS CONTAINED IN THE MAP.

The greater portion of the area under description is occupied by strata of Silurian age, arranged in parallel bands from south-west to north-east. After the Silurian rocks had been elevated and thrown into innumerable plications, they were pierced by massive igneous rocks, of which one of the three large granite masses of Galloway is included in this area. It extends continuously from Criffel to Dalbeattie and Bengairn. From Screel westwards to the valley of the Dee, the Silurian rocks are traversed by minor bosses, dykes, and veins of various igneous materials connected with the granite complex. Evidence will be adduced on a subsequent page to show that these igneous masses must have been exposed by denudation prior to Upper Old Red Sandstone time, as they furnished materials for the conglomerates, grits, sandstones, and beds of arkose occurring in the Upper Old Red Sandstone and Lower Carboniferous series.

Representatives of the Upper Old Red Sandstone underlie the lavas of the Kirkbean district. Outliers of the Calciferous Sandstone series occur on the shore, between the Dee and the Urr, and at Glenstocking and Portowarren on the Colvend shore; but the largest area is met with in the belt of fertile ground extending from Mainsriddle by the village of Kirkbean to the Drum Burn, where there is a sequence from the base of the Cement-stone series to the Coralline limestone of Arbigland.

SILURIAN.

The Silurian rocks of this district are mainly of Llandovery age, forming a broad belt, 13 miles in width, which stretches from the granite mass at Loch Skerrow to the shores of Kirkcudbright Bay. Rising from underneath these sediments, along different anticlinal folds, frequently inverted and truncated by faults, various sub-divisions of the Moffat Black

Shale series are met with. In the southern part of the area, between Kirkcudbright Bay and the granite mass of Bengairn, these Llandovery rocks pass conformably upwards into beds of Wenlock age.

The researches of Professor Lapworth among the Silurian rocks of the south of Scotland furnished the key for the interpretation of the complicated stratigraphy of this ancient Silurian tableland. By means of the vertical distribution of the graptolites he established the true order of successien of the strata, and correlated them with their equivalents in Wales and other regions. In a forthcoming Geological Survey Memoir on 'The Silurian Rocks of the Southern Uplands,' a chapter is devoted to the history of research in these ancient sediments. In anticipation of detailed references to Professor Lapworth's investigations, we may indicate the following points established by him, which have a special bearing on the geological structure of the area under consideration. (1) In his paper on 'The Moffat Series' (*Quart. Journ. Geol. Soc.*, vol. xxxiv. p. 240, 1878), he demonstrated the existence of three faunas characteristic of the three successive divisions of the Moffat shales, viz., the Glenkiln, Hartfell, and Birkhill groups, and correlated these divisions with the Upper Llandeilo, Caradoc, and Lower Llandovery formations respectively. (2) He further showed that, to the south of the Ettrick, the group of sediments of Llandovery age overlying the Birkhill shales, after innumerable plications on Eskdalemuir, pass conformably upwards into the Wenlock strata of Riccarton, Kirkcudbright, Mosspaul, and the Slitrig. (3) In his paper on 'The Ballantrae Rocks of the South of Scotland and their Place in the Upland Sequence' (*Geol. Mag.*, vol. vi., 1889), he conclusively proved that the complicated stratigraphical relations of the strata can be unravelled by means of the graptolite fauna, illustrating the structure of the tableland by a series of horizontal sections. (4) In the latter publication he announced that in 1885 he discovered, in hardened black shales, on the shore at Bennane Head, a middle Arenig fauna, thus fixing the age of part of the Ballantrae volcanic series, the igneous character of which had been previously recognised and described by Professor Bonney.*

The discovery of the organic origin of the Radiolarian Cherts and their association with interbedded and intrusive volcanic rocks was made in 1888, in the course of the re-examination of the Abington area by the Geological Survey, and has proved of great service in unravelling the stratigraphy of part of the tableland.

The various exposures of the Moffat series in the present Sheet have been re-examined, and the zones have been compared with their representatives in the typical Moffat region. The sections are here so imperfect and in many instances the strata have been so shattered and truncated by faults that their true relations are difficult to ascertain. It appears, however, that the various zones, ranging from the Radiolarian Cherts and associated tuffs of Arenig age to the horizon of the Lower Birkhill shales, occur in some of the folds.

Black Shale Bands within the Llandovery Area.

Trowdale, Crossmichael, and Lawrieston Bands.—Along a line extending from Tottlehams Burn and Trowdale Glen by Crossmichael to Lawrieston, there are exposures of the Moffat series. Though nearly in the same line of strike, they occur on separate folds. Of these exposures, the most important are those in Trowdale Glen, Tottlehams Burn, and adjoining fields, in the valley of the Urr, about 4 miles north of Castle-Douglas, which will be first described.

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* 'On the Serpentine and Associated Igneous Rocks of the Ayrshire Coast.' By T. G. Bonney (*Quart. Journ. Geol. Soc.*, vol. xxxiv. p. 769, 1878.)

On the west bank of the Urr, in the fields immediately to the south of Trowdale Glen, the lowest beds are exposed. They consist of Radiolarian cherts, mudstones, and shales, associated with fine felsitic tuff. These strata are inclined to the north-west at high angles, and plunge underneath the band of Glenkiln-Hartfell black shales exposed in the Trowdale Glen. There is one peculiar band of shales which breaks under the hammer into pencil-shaped fragments, exposed in a small hollow about 120 yards to the south of Trowdale Glen in the midst of ashy mudstones and cherts. It is highly probable that this band and even others associated with it may yield Arenig graptolites, though a careful search has hitherto failed to bring them to light. The volcanic tuff is well seen in knolls close to Trowdale Wood, and it likewise forms a prominent feature in the wood to the south of the Glenkiln black shales. The lithological character of this rock is rather interesting. The common variety is a dull pinkish-grey rock, which, on weathered surfaces, has a yellowish tint. It has a curious speckled appearance, owing to the presence of pink or yellow spots in a grey matrix. Sometimes the rock is compact, has a uniform colour, and breaks with a conchoidal fracture.

The intercalation of some of these felsitic tuffs between the Glenkiln black shales and the Radiolarian cherts seems to indicate the continuance of volcanic conditions in that area in Llandeilo time. Abundant evidence has been obtained of similar phenomena during the re-examination of the volcanic area south of Ballantrae.

Proceeding to the section in Trowdale Glen, we find the Glenkiln black shales near the entrance, and they may be followed along the south bank for a short distance up stream. They consist of black flinty ribs, with black shale partings passing upwards into the Hartfell black shales, which are in turn overlain by the Barren Mudstones, forming the north cliff in the lower part of the glen.

The black shales in the ravine have yielded the following fossils :—

Didymograptus superstes, Lapw.
Cœnograptus gracilis, Hall.
,, *nitidulus*, Lapw.
,, *pertenuis*, Lapw.
Diplograptus Whitfieldi, Hall.
,, *foliaceus*, Murch.
Clathrograptus cuneiformis, Lapw.

Cryptograptus tricornis, Carr.
Climacograptus cœlatus var. *antiquus* Lapw.
,, *bicornis*, Hall.
Dicellograptus Forchhammeri, Geinitz.
,, *Moffatensis*, Carr.

The Birkhill shales are not visible in the Trowdale Glen to the north of the Barren Mudstones, but a small exposure is seen on a footpath about half a mile east of Balgerran Farmhouse, in the strike of the Trowdale band, which yielded fragments of *Dimorphograptus*.

From the foregoing description it is apparent that the strata in the neighbourhood of Trowdale form the northern limb of a fold, the lowest beds being the Radiolarian cherts and volcanic tuffs, and the highest, some member of the Birkhill black shales.

Southwards towards the Mountskip Plantation, however, the relations of the strata are disturbed by faults. The southern limb of this fold cannot be traced. Greywackes of Llandovery age rapidly follow the cherts in the field to the south of Trowdale Glen. They are also visible in a burn in the Mountskip Wood. It is clear that a fault must intervene, bringing these different zones in contact with each other. Again, in the burn in this plantation, about 200 yards west from the Castle-Douglas

Road, there is a small exposure of black shales from which the following Glenkiln forms were obtained :—

Didymograptus superstes, Lapw.
Diplograptus bimucronatus, Nich.
Cryptograptus tricornis, Carr.
Dicellograptus Moffatensis, Carr.
Dicellograptus Forchhammeri, Geinitz.
,, ,, var. *flexuosus*, Lapw.

The relations of these shales to the surrounding rocks are not visible; but above the forkings of this burn, in the south branch, the Barren Mudstones are met with. This exposure is also isolated. The nearest visible rocks consist of Llandovery greywackes and shales, the horizon of which is clearly defined by certain fossils occurring in a small quarry on the north side of Mountskip Plantation, and about 500 yards south of Trowdale Glen. Here a dark band yielded the following forms :—

Aptychopsis minus, Barr.
Diplograptus palmeus, Barr.
Monograptus exiguus, Nich.
Monograptus turriculatus, Barr.
,, *tenuis*, Portl.
,, *attenuatus*, Hopk.

The presence of *Monograptus exiguus* and some of its associates indicates a higher horizon than the *Rastrites maximus* band at the top of the Birkhill group.

Tottlehams Burn.—Proceeding now to the extension of this band in a north-east direction, we find that the Radiolarian cherts and mudstones are not visible in the Urr, owing to the alluvial covering. But at the mouth of the Tottlehams Burn there is a fine exposure of the Barren Mudstones in the river. A few yards below the junction of this stream with the Urr, a band of black shales, yielding *Climacograptus Schärenbergi*, *Dicranograptus*, &c., occurs in the mudstones, possibly representing a part of the Hartfell black shales in an isoclinal fold. There the strata dip in a uniform direction towards the north-west at high angles.

Advancing up the Tottlehams Burn, the observer can trace the Barren Mudstones with the characteristic features of the zone. These strata contain nodules composed of oxides of iron and manganese, the latter predominating. From an examination of one of the cores of these nodules by Mr Teall, it appears that it is a carbonate of manganese and iron. It is traversed by a vein, black in the middle, brown at the margins, fading off gradually into the surrounding rock. There are also peculiar structures, probably organic, in this rock. From these data he infers that the rock was originally a limestone, that it was subsequently changed to a carbonate of manganese and iron, and finally that the carbonate was decomposed under oxidising conditions so as to give rise to the nodular masses of the oxides of manganese and iron.

At the Mill, alongside of the public road, the Glenkiln-Hartfell black shales appear in the burn and the mill-lead, rising from underneath the Barren Mudstones. The following fossils characteristic of these groups were here obtained :—

Cœnograptus gracilis, Hall.
,, *explanatus*, Lapw.
Didymograptus superstes, Lapw.
Diplograptus foliaceus, Murch.
Climacograptus Schärenbergi, Lapw.
,, *caudatus*, Lapw.
Retiolites fibratus, Lapw.
Dicellograptus Forchhammeri, Geinitz.

The Barren Mudstones are seen in the mill-lead for about 80 yards above the mill. From the mill pond, for a distance of 500 yards up stream, the rocks are concealed by boulder clay; but at the eastern edge of the Tottlehams Wood, the Barren Mudstones appear on the south bank of the stream, succeeded on the south by a small exposure of the Birkhill shales, yielding, amongst other forms, *Diplograptus acuminatus*, *Climacograptus normalis*, &c. Here the stream-course changes and bends towards the north. On the north-east side of the stone fence crossing the burn at this point, there is a small exposure of black shales charged with *Climacograptus caudatus*, *Diplograptus*, and *Dicellograptus Moffatensis*, characteristic of the Lower Hartfell group. They are followed by Llandovery greywackes to the south, so that a fault must here come between these zones. They must be truncated also by a north and south fault, bringing them in contact with the Barren Mudstones and Birkhill shales just described.

From the prominent bend in the Tottlehams Burn above referred to, north-eastwards by Corsehill and Barmofitty, the members of the Moffat series can be traced for a distance of about half a mile, partly by means of rocky knolls peering through the drift. The bands of felsitic tuff with cherts and mudstones can be followed in isolated exposures to the fields west of Barmofitty Farmhouse. They are inclined to the north-west at high angles. On the north side they are succeeded by the Glenkiln-Hartfell black shales visible in the Tottlehams Burn and in the fields south-west of Corsehill. On the south side of the fold there is one excellent exposure of black shales charged with graptolites of the Glenkiln horizon, in abundance and excellent preservation. It occurs on a knoll about 150 yards north of the east end of Tottlehams Wood. Here the black shales are repeated by folds, and the grey Radiolarian cherts are brought to the surface in two sharp anticlines. The following list of fossils was collected at this locality:—

Cœnograptus gracilis, Hall.
,, *surcularis*, Hall.
,, *pertenuis*, Lapw.
,, *explanatus*, Lapw.
,, *nitidulus*, Lapw.
Didymograptus superstes, Lapw.
,, *serratulus*, Hall.
Diplograptus bimucronatus, Nich.
,, *dentatus*, Broug.
,, *foliaceus*, Murch.
Cryptograptus tricornis, Carr.
Hallograptus mucronatus, Hall.
Diplograptus Whitfieldi, Hall.
Glossograptus Hincksii, Hopk.
Climacograptus bicornis, Hall.
,, *cœlatus* var. *antiquus*, Lapw.
Dicellograptus sextans, Hall.
,, *Forchhammeri*, Geinitz.
,, ,, var. *flexuosus*, Lapw.
,, *Moffatensis*, Carr.
Dicranograptus tardiusculus, Lapw.
,, *ramosus*, Hall.
Clathrograptus cuneiformis, Lapw.
Siphonotreta micula, M'Coy.

Returning now to the prolongation of the Trowdale band in a south-west direction towards Kilnotrie and Crossmichael, we find only isolated exposures of the Moffat series protruding through drift. In the strike of the outcrops south of Trowdale Glen, the Radiolarian cherts, mudstones, shales, and volcanic tuffs are met with in fields about a third of a mile south-east of Balgerran Farmhouse, the general dip being to the north-west. On the north side of the fold the foregoing strata are succeeded by the Glenkiln-Hartfell shales, which, at an old mine about one-third of a mile E.S.E. of Balgerran, yielded :—*Cœnograptus gracilis*, *Clathrograptus cuneiformis*, *Climacograptus bicornis*, *C. cœlatus* var. *antiquus*, *Diplograptus foliaceus*, *Dicellograptus Moffatensis*, *Siphonotreta micula*.

Again, on the south side of the cherts and mudstones, in a field north-west of Mountskip Plantation, and not far to the north of the *Monograptus exiguus* band already referred to, soft black shales appear at the side of a streamlet. Some characteristic Glenkiln forms, with others, have been gathered at this locality :—

Didymograptus superstes, Lapw.
,, nov. sp. with disc.
Cœnograptus gracilis, Hall.
Thamnograptus typus, Hall.
Diplograptus euglyphus, Lapw.
,, *Whitfieldi*, Hall.
Diplograptus foliaceus, Murch.
Cryptograptus tricornis, Carr.
Climacograptus bicornis, Hall.
,, *cœlatus* var. *antiquus*, Lapw.
Glossograptus Hincksii, Hopk.

By means of a synclinal fold the Barren Mudstones appear to the south of this exposure, followed by the Glenkiln shales, charged with *Cœnograptus gracilis, Diplograptus Whitfieldi, D. bimucronatus, D. foliaceus, Climacograptus bicornis, Dicellograptus*, &c.

Proceeding westwards to the Kilnotrie Farmhouse, the observer finds the cherts and volanic tuffs in the fields to the north of the steading, and they may be followed west to a point south of Erncrogo Loch. They occur on a different anticlinal fold from that of the Trowdale band, though not far to the south. The Glenkiln-Hartfell black shales and Barren Mudstones occur on the north side of the anticline in the fields near Erncrogo Loch, and on the south side in the fields to the east of Kilnotrie. A few yards west of Kilnotrie Farmhouse the following Hartfell assemblage was obtained :—*Climacograptus caudatus, C. bicornis, Diplograptus foliaceus, D. tricornis, Dicellograptus Moffatensis.* Again, at Crossmichael, the black shales are visible near the south end of the village, and the felsitic tuffs on the slope north-east of this locality, but their relations to the surrounding rocks are not apparent.

Still further to the south-west in the neighbourhood of Lawrieston, the volcanic tuffs and Radiolarian cherts are to be seen at one or two localities, south of Bellymack Farmhouse, and about half a mile east of the village. Here they are associated with black shales, visible in a small burn east of South Quintenespie, charged with *Didymograptus superstes, Diplograptus bimucronatus, Cryptograptus tricornis, Climacograptus bicornis, Dicellograptus Moffatensis, D. Forchhammeri*, &c. The black shales likewise appear at the roadside a few yards west of Bellymack.

About a mile to the south-west of the foregoing locality, representatives of the Birkhill black shales come to the surface along an axial fold in the Llandovery greywackes and shales. From the assemblage of fossils, it is apparent that the members of the Lower Birkhill division are here met with, ranging from the *Diplograptus acuminatus* zone to that of *Monograptus gregarius.* In the stream, about fifty yards to the north of Dunnance Farmhouse, black shales are exposed, dipping to the north-west, from which the following list of fossils was obtained :—

Diplograptus acuminatus, Nich.
,, *vesiculosus*, Nich.
Climacograptus normalis, Lapw.
Dimorphograptus, Nich.

Monograptus tenuis, Portl.
,, *attenuatus*, Hopk.
,, *lobiferus*, M'Coy.
Dawsonia campanulata, Nich.

In one of the branches of this stream, about one-third of a mile south-west of Dunnance Farmhouse, in the same line of strike, the black shales yielded :—

Diplograptus acuminatus, Nich.
,, *tamariscus*, Nich.
Climacograptus normalis, Lapw.
Monograptus tenuis, Portl.
,, *attenuatus*, Hopk.
,, *leptotheca*, Lapw.

Monograptus jaculum, Carr.
,, *triangulatus*, Hark.
,, *gregarius*, Lapw.
,, *lobiferus*, M'Coy.
Lingula striata.

At this part of the stream-section the black shales are repeated several times by isoclinal folds inclined to the N.N.W. in conjunction with the Llandovery grits and shales.

Hensol Black Shale Band, River Dee.—Owing to plications of the overlying Llandovery grits and shales, the members of the Moffat series reappear about three miles to the north of the Lawrieston band, in the River Dee at Hensol House, close to its junction with the Ken. This exposure is of special interest, as the strata are arranged on the whole in a normal fold, the lowest beds occupying the core of the arch. On the north bank of the river, at the bend, a quarter of a mile below Hensol House, where the section occurs, Barren Mudstones form the centre of the fold, succeeded on both sides by the Lower Birkhill shales. At the top of the Barren Mudstones, on the south side of the arch, *Dicellograptus anceps* was obtained from black shales pierced by an intrusive dyke. A band of black grits is associated with the Birkhill shales on the south limb of the arch; the latter being inclined to the south-east at high angles. In like manner, the Lower Birkhill zones dip away from the Barren Mudstones on the north side of the fold. The Birkhill shales have here yielded the following forms:—

Diplograptus vesiculosus, Nich.
,, *tamariscus*, Nich.
Dimorphograptus elongatus, Lapw.
Climacograptus normalis, Lapw.
Monograptus tenuis, Portl.
,, *attenuatus*, Hopk.
,, *gregarius*, Lapw.
Dawsonia campanulata, Nich.

It is worthy of note that the highest zone represented here is that of *Monograptus gregarius*, as the Llandovery greywackes and shales immediately succeed in the railway cutting to the north.

These members of the Moffat series can be traced down the river Dee for a short distance along the strike, and they are also visible in the railway cutting to the north.

A small exposure of the Birkhill shales occurs on another fold near the railway viaduct on the east bank of the Ken.

Not far from the granite boundary, in the north-west corner of the Map, there are two outcrops of black shales, one on the south slope of Bennan Hill, south of Loch Stroan, and the other in Clenoch Burn. A third exposure is seen in the Castramont Burn about two miles from the granite margin. In these instances, the Moffat shales come to the surface along isoclinal folds, inclined to the south-east, but the beds are too much altered to yield graptolites.

Black Shale Bands between Gatehouse-of-Fleet and Tarff Water.

Barlay Burn.—About two miles to the north-east of Gatehouse, at a marked bend in the Barlay Burn, representatives of the Lower Birkhill group appear, much contorted and traversed by faults. At the first exposure, in the ascent of the burn, the black shales are cleaved and corrugated, dipping to the south-east at low angles. Here they have yielded specimens of *Climacograptus normalis.* A few feet above this outcrop, thin bands of black shales with seams of white clay occur, from which have been obtained *Monograptus triangulatus, M. tenuis, M. lobiferus*, and *Climacograptus normalis.* These are overlain by grey shales. A fault running in a north-west and south-east direction bounds these beds on the west side, bringing them into conjunction with grey greywackes. Further up stream the band is traversed by two faults, but the shales are traceable as far as the bridge across the burn. A thin band at this north-east exposure yielded *Diplograptus acuminatus, D. tamariscus, Monograptus tenuis*, &c. Near the bridge, *Monograptus gregarius* and some of its associates were found.

Coal Heugh.—In this small tributary of the Tarff Water, and also in the Tarff section, the Birkhill shales are visible on another fold. Indeed, the Coal Heugh receives its name from this outcrop of black shales, which led to excavations in search of coal. Ascending the Tarff from Ringford, we find brown-crusted flags, blue shales, and fine grained greywackes, inclined to the north-west. On the west bank of the Tarff, opposite Liggatcheek, and near the mouth of Coal Heugh, shattery green shales, flags, and jointed greywackes veined with calcite appear. These are succeeded by grey shaly clays and thin bands of black shale. They are prolonged up the Coal Heugh, the best exposure being at the site of an old mine. The beds are much slickensided, and fossils are difficult to obtain, but specimens of *Diplograptus acuminatus* and *Climacograptus normalis* were here collected.

From the evidence adduced in the foregoing pages, it appears that the highest zone represented in the Black Shale bands in this Sheet is that of *Monograptus gregarius*. The Moffat type of the Upper Birkhill division has not as yet been detected in this area. It is probably represented by some of the coarser sediments. The occurrence of *Monograptus Sedgwicki*, Portl., in a dark seam interleaved in greywackes and shales in the Tarff Water west of Upper Lairdmannoch seems to support this conclusion.

To the south-west of the Coal Heugh, on the south slope of the Culcaigrie Hill, and also near the Benjarg Wood, a dark seam in greywackes and shales has yielded *Monograptus exiguus*, which, as already indicated, belongs to a higher horizon than any of the Birkhill zones.

Llandovery Rocks overlying the Birkhill Shales.

Reference has already been made to the broad belt of sediments, of Llandovery age, 13 miles in width, stretching from the granite mass at Loch Skerrow to the base of the Wenlock Rocks in Kirkcudbright Bay. Professor Lapworth has demonstrated on palæontological grounds that the Birkhill shales form the true base line of the Llandovery rocks in the south of Scotland. In the present area, the sections of the Birkhill shales are not numerous, even in the case of the Trowdale and Lawrieston band, where the Moffat series is best developed. The strata following next in order in the northern portion of the area consist of (1) flags and shales with greywacke bands, (2) massive (Queensberry) grits and greywackes. The grits are usually of a purple colour, and the flags are red and grey. To the north of the Moffat shales, at the village of Lawrieston, the reddish-grey flags and shales follow in regular sequence, and dip underneath the coarse purple grits of the Livingstone and Dornell Hills. By means of folding, the grits spread northwards to the slope of Ulloch Hill. From Drumglass north to the Hensol Band of the Moffat shales there are several rapid plications of the flaggy series at the base. The features of this shaly series may be studied in the Parton slate quarries, where they have a reddish tint like the grits associated with them. A distinguishing characteristic of the grits is the massive bedding and tabular jointing, so prevalent on the hills to the north of Lawrieston. These features are likewise seen on the Kirkconnel Moor above the Coal Heugh.

The only fossils obtained from these beds are those already quoted from the *Monograptus exiguus* band at or near the base of the series. The presence of this zone near Trowdale and to the south near Gatehouse helps to correlate the sediments in these widely separated areas. Apart from the various folds of the underlying Moffat shales, the intense plication of the Queensberry grits and shales is proved by the existence of rapid folds, both normal and inverted, in the latter series.

Proceeding southwards towards Castle-Douglas, and thence to Kirkcudbright Bay, the observer finds that the massive grits give place to a different series of strata (Hawick Rocks, Ardwell Beds).

The members of this group consist of brown-crusted flags from three to six inches thick, with green, grey, and in some instances red shales. These are associated with brown, yellow, or ochreous greywackes from one to two feet thick. Frequently the shales are very fissile, splitting in thin laminæ, and they often occur in zones from twelve to twenty feet in breadth. Though the dominant type of the series is flaggy, yet in certain areas bands of greywacke and grit can be traced for considerable distances. These usually break up into angular blocks. From the oxidation of their iron, the rocks weather with a brown crust to the depth of about half an inch, but on a fresh fracture they are grey or blue. Veins of quartz frequently traverse the beds, and the joints are often coated with carbonate of lime. Many of the flags and greywacke bands effervesce with acids.

The zones of shales throughout the area are more or less cleaved. On the west side of Kirkcudbright Bay, north of Bar Point, the direction of the strike is N. 35° E., while that of the cleavage is E. 23° N. Again, in the Borness Cliffs, in the parish of Borgue, the direction of the strike is N. 36° E., and that of the cleavage about E. 30° N. The prevalent trend of the cleavage planes throughout the area is about E.N.E. and W.S.W.

The best section of the Llandovery group occurs on the shore between the mouth of the Fleet and the Meikle Ross on the west side of Kirkcudbright Bay. There the innumerable plications of the strata may be seen to advantage, especially between Knockbrex and Kirkandrews Bays. So rapid are the folds that upwards of sixty anticlines and synclines have been mapped between Corseyard Point and Knockbrex, a distance of one mile and a quarter. Many of the folds are inverted. The prevalence of isoclinal folds in strata of such uniform lithological character shows how natural it is to exaggerate the thickness of these sediments when one trusts merely to apparent superposition. Indeed, it frequently happens that beds dip in one direction for a considerable distance, while along the same line of strike they may be normally folded. For example, on the shore section, on the west side of the estuary of the Dee, between the Doon and the base of the Wenlock rocks, the strata, with certain exceptions, are inclined to the south-east. But along the same line of strike, round the shores of Falbogue and Bridgehouse Bays, onwards to the Borness cliffs, they rarely have a persistent dip in one direction. There can be little doubt that they are as much folded in the one case as the other.

This group of strata is singularly destitute of fossils. At Castle-Douglas Station, in the railway cutting at Halketleaths Mill, and on the east shore of Kirkcudbright Bay, about 300 yards north of Torr Point, *Protovirgularia Harknessi* has been obtained.

Ludlow and Wenlock Groups.

The representatives of these divisions of the Silurian system occur along the southern margin of the Silurian area. They occupy a belt of ground, stretching from the shores of Kirkcudbright Bay east by Dundrennan to the granite complex. A strip of altered strata belonging to the same series is traceable along the shores of the Solway Firth to the hill slopes south-east of Criffel. The character of the strata is admirably seen on the coast-sections, specially on the east side of Kirkcudbright Bay and onwards to White Port, where they are unconformably overlain by the basement breccias of the Lower Carboniferous rocks.

The strata may be grouped into two sub-divisions given here in descending order :—

(*a*) Green and olive shales, with limestone-nodules, grey sandy flags, and thin bedded greywackes, with occasional bands of fossiliferous grit and conglomerate.

(*b*) Yellow or brown-crusted greywackes and grits, with flags and shales. The chief characteristic of the group is the constant occurrence of dark shales charged with graptolites.

The members of the lower group occur on both sides of Kirkcudbright Bay. On the eastern shore, they extend from the base line at Long Robin to near the mouth of Balmae Burn. Here there is a constant repetition of well-bedded greywackes, grits, and flags with pale and dark coloured shales. On weathered surfaces, the greywackes have a brown tint; on fresh fracture they are grey or blue. Their average thickness varies from one to two feet, and in some instances it amounts to three feet. The pale coloured shales are argillaceous, and are frequently cleaved, the cleavage planes trending in the same general direction as those in the Hawick type of the Llandovery group already described. The graptolite bands differ lithologically from the black shales of the Moffat series. Weathering with a dark brown crust, they have a dark colour on fresh fracture and also a fibrous texture. They sometimes occur in zones from ten to twelve feet in breadth; and, on the other hand, it occasionally happens that thin leaf-like seams, charged with graptolites, alternate with the barren pale coloured shales and flags of the group. At one locality, on the shore near Witchwife's Haven, limestone-nodules occur in one of these graptolite bands.

From the boundary line at Long Robin southwards to near the mouth of Balmae Burn, the lower sub-division of the Wenlock beds is repeated by rapid folds, as long ago pointed out by Professor Harkness.[1] The plications are so numerous that no well-marked axis can be traced inland from the shore. Indeed, from the frequent changes of dip, it is evident that the various outcrops of graptolite-shales are merely repetitions of a few bands. Towards the south, in the broader synclinal folds, the members of the overlying sub-division are to be found. The exposures of the graptolite-shale series on the cliff at Clinking Cove, west of Raeberry Castle, and again, still further to the south-east, in Mulloch Bay, are evidently due to anticlinal folds; the intervening areas being occupied by younger strata.

Few species of graptolites occur in the graptolitic bands. They include *Monograptus vomerinus*, *M. priodon*, *M. Riccartonensis*, *M. colonus* (?), *M. Flemingii*, *Cyrtograptus Murchisoni*, and *Retiolites Geinitzianus*. Fragments of crustaceans and orthoceratites are associated with the graptolites. The carapace of a crustacean—*Aptychopsis oblata*, Jones—was found in one of the graptolite-bands immediately to the south of Torr's Cove Bay. Many of the orthoceratite remains are so fragmentary that the species are hardly determinable. The best specimens have been obtained near the Witchwife's Haven, Torr's Point, and Balmae Haven. The strata associated with the graptolite-bands of the lower sub-division have hitherto yielded no organic remains.

The members of the lower sub-division also occur on the west side of Kirkcudbright Bay, round the shores of Balmangan and Falbogue Bays, in the peninsular tract of Meikle Ross and in the island of Little Ross. Here, also, they present the same features as those already indicated, and they have yielded similar organic remains. Near the base, south of Shaw Hole, and to the north of Balmangan Bay, *Cyrtograptus Murchisoni* is one of the characteristic forms.

The graptolite-bearing series has been traced from the east shore of Kirkcudbright Bay to the contact zone round the granite of Auchencairn and Bengairn. At various localities throughout this belt of ground, graptolites have been obtained from the dark bands. No fossils have been exhumed from the strip of altered Upper Silurian strata along the

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[1] *Quart. Journ. Geol. Soc.*, vol. ix. p. 183.

Colvend shore; but graptolites and orthoceratites have been found in the Wenlock beds in the Kirkbean Burn to the south-east of Criffel.

The members of the higher sub-division are admirably seen on the shore between the mouth of Balmae Burn and Howell Bay, along the Raeberry Cliffs and between Mulloch Bay and White Port. The most prominent members of the series are green and olive shales, with fossiliferous limestone-nodules and ripple-marked sandy flags. These are occasionally associated with sandstones, grits, and bands of fossiliferous conglomerate. They seem to have been deposited in shallow water on a shelving platform, subject to gentle earth movements. The fossiliferous brecciated conglomerates, intercalated with the olive shales, are evidently old beach deposits. The gradual thinning out of the sandstones and grits, and the overlapping of the flags and shales, point to repeated changes in the distribution of the materials by currents along the shore.

Beginning with the small trough north of Gipsy Point, the following is the arrangement of the strata, from the Balmae Burn south to the reappearance of the graptolite-bearing bands in Howell Bay. Immediately to the north of the mouth of Balmae Burn, a fault occurs with a downthrow to the west. On the east side of this fault, the strata consist of brown-crusted greywackes, shales, flags, and graptolite-bands, dipping to the south-east at 70°. These are succeeded by green fissile shales, with bands of flaggy shales from 2 to 3 inches thick. For a short distance the beds are inclined to the north at high angles, being here inverted, but they soon dip to the south-east at an angle of 80° till they pass underneath a lenticular band of fine conglomerate at the mouth of Balmae Burn, which may be the attenuated representative of the fossiliferous conglomerate at Gipsy Point, on the south side of the trough.

Southwards, the foregoing band of conglomerate is overlain by olive shales and flags, intersected with veins of calcite, which, within a short distance, have a return dip to the north-west at high angles. Here a zone of finely laminated olive shales, with limestone-nodules, is exposed on the shore, succeeded by ripple-marked greywackes, flags and shales, graduating into the coarse grits and conglomerates at Gipsy Point. At this locality some excellent examples of the gradual thinning out of bands of grit are visible on the beach and on the cliff. Two outcrops of conglomerate at this headland lie about 70 yards distant from each other. The matrix of the rock is a grey grit, in which are embedded pebbles of greywacke and grits, with angular pieces of shale and rounded grains of quartz.

The north band of conglomerate has yielded casts of *Pterinea* and *Petraia;* and the south band *Petraia elongata, Favosites,* casts of *Heliolites, Spirifera, Ptilodictya, Cornulites,* and a fragment of a trilobite.

Between these outcrops of fossiliferous conglomerate there is a zone of gnarled green shales containing lenticular patches of coarse grit and numerous nodules of limestone which measure from a few inches to a foot across and have yielded some of the best preserved fossils. Similar shales reappear on the south side of the southern outcrop of conglomerate at Gipsy Head, veined abundantly with carbonate of lime. They dip to the north-west at angles of from 83° to 88°, and can be traced along the western shore of Howell Bay to the centre of the bay. Among the fossils obtained from the limestone-nodules may be mentioned —*Orthonota, Murchisonia obscura, Ctenodonta, Cucullella, Bellerophon trilobatus.*

In the centre of Howell Bay, this series of olive shales, with limestone-nodules and fossiliferous conglomerates, is brought into conjunction with the underlying graptolite-bearing series by means of a fault with a downthrow to the west. Here the strata are traversed by several small faults which have interfered with the natural stratigraphical sequence. But on the cliff on the east side of the bay, the graptolite-bearing beds are inclined to the north-west; while east of the headland, towards Clinking Cove, the prevalent dip is to the south-east. These beds are apparently brought to the surface along an anticlinal fold traceable eastwards to the centre of the bay west of Raeberry Castle. The strata consist of brown-crusted greywackes with shaly partings, and the characteristic graptolite-shales. The latter are best seen at Brandy Craig on the east side of Howell Bay. Here they have yielded specimens of *Monograptus vomerinus* and *Dictyocaris.* The occurrence of *Monograptus vomerinus,* close to the olive mudstones and shales, with limestone-nodules, is worthy of note, as it is one of the forms occurring in the higher graptolite-bands in the Wenlock group of the south of Scotland.

In the centre of the bay, west of Raeberry, the graptolite-bearing series is much disturbed by faults, and has been thrown into a series of sharp folds. It is traversed by a number of intrusive dykes, of which only a few could be engraved on the one-inch Map. On the east side of the bay, the strata have a persistent dip to the south-east, in the direction of Raeberry Point, where they consist of ripple-marked micaceous sandstones, flags, and olive shales. The thinning out of the gritty sandstones is well displayed on the beach at this locality, and occasionally small seams and pockets of sand may be observed in the shales. At Raeberry Point a beautiful specimen of *Orthoceras Etheridgei,* Blake, was found in the flaggy shales with limestone-nodules; indeed, upwards of fourteen examples of this species were here obtained. Professor Harkness also found specimens of *Terebratula lacunosa* and *T. semisulcata.*

From Raeberry Point eastwards to the mouth of Dunrod Burn, there is a continuous section of grey, flaggy sandstones, in beds averaging from 6 to 12 inches in thickness, flaggy shales, and green fissile shales. A zone of olive shales with small limestone-nodules, occurs immediately to the west of Robb's Craigs, in the centre of which a band of coarse grit is seen forming a prominent feature on the beach. A striking characteristic of the sandstones and flags on the beach at Raeberry is the prevalence of ripple marks. The cliffs display excellent examples of the rapid folds and inversions of the strata, and of the variations in direction of dip along the same line of strike.

These strata just referred to are not prolonged eastwards into Mulloch Bay in the centre of which the graptolite-bearing strata appear, forming skerries on the beach. Well-preserved graptolites have been obtained from the dark bands associated with the greywackes at this locality. It is evident that a fault intervenes with a down-throw to the west, as indicated on the Map.

The section exposed on the beach from the mouth of the Quartercake Burn on the side of Mulloch Bay, south to Netherlaw Point and onwards to White Port, closely resembles that between the mouth of the Balmae Burn and Howell Bay already described. The beds are inclined to the west of north, and there is a similar descending series from the olive shales with limestone-nodules at the mouth of the Quartercake Burn to the fossiliferous conglomerate and associated shales at Netherlaw Point. At the White Port the green shales have been reddened by the infiltration of iron oxide from the overlying red breccias at the base of the Carboniferous system.

The members of the upper sub-division are also exposed at Abbey Burnfoot, in the lower reaches of the Abbey and Netherlaw Burns and also in the Dunrod Burn, north of Burnside. A band of fine brecciated conglomerate is exposed at the farm-house of Little Balmae, which has yielded the following assemblage of organic remains :—

Petraia elongata, Phill.
,, *bina*, Lons.
Favosites, sp.
Stenopora fibrosa, Goldf.
Syringopora.
Heliolites, sp.
Encrinite stems.
Cornulites.
Ptilodictya.
Phacops caudatus.
Spirifera.
Leptæna sericea, Sow.
Orthis calligramma, Dalm.
,, *Bouchardii*, Day.
Pterinea.
Murchisonia.

In a review of the palæontological evidence obtained from the strata overlying the Llandovery rocks in Kirkcudbright Bay, it is clear that the graptolites, though numbering few species, are of great service for purposes of correlation. The fossils collected by Mr Fleming and the Rev. Mr Underwood, forwarded to the Geological Society of London by the Earl of Selkirk, led Mr Salter to the conclusion that the strata are of Wenlock age—a view which was confirmed by the evidence obtained by Professor Harkness. There can be no doubt that the graptolite-bearing series belongs to this division of the Silurian system. As already indicated, the lowest graptolite-band on the west side of Kirkcudbright Bay yields *Cyrtograptus Murchisoni*, and the highest bands in contact with the olive shales with limestone-nodules, *Monograptus vomerinus.* But from some of the fossils obtained from the limestone-nodules, it is probable that the sub-division comprising the olive shales may be of Ludlow age.

Igneous Rocks in Silurian Areas.

The Granite Mass.—A striking feature in the south-east portion of the county of Kirkcudbright is the large mass of granite surrounded by a network of dykes traversing the Silurian rocks. It stretches from Kirkconnel on the banks of the Nith to Bengairn, a distance of sixteen miles, with an average breadth of six miles east of the valley of the Urr. As already stated, it is one of the three great masses of granite in Galloway, covering upwards of seventy-five square miles of ground.

The longer axis of the mass runs in a north-east and south-west direction, in accordance with the general strike of the Silurian rocks. It pierces strata, on the north side of Llandovery age, and on the south side of Wenlock age. From an examination of the relations of the granite to the Silurian rocks east of the valley of the Urr, it is apparent that, on the north-west side, the strata generally dip away from the igneous mass, while they do so also along the shores of the Solway on the south-east side. This feature is conspicuous on the hill slopes east of Southwick, where the inclination of the surface of the granite mass at the margin roughly coincides with the angle of dip of the Silurian strata.

The disruptive character of the mass is strikingly apparent in the deep valley between Screel and Bengairn, where the boundary-line crosses the strike of a great escarpment of altered Silurian rocks. Again, for several miles along the western margin, from Bentuther to a point near Rascarrel Bay, the Silurian rocks are truncated by the granite without any deflection of the strike. Westwards in the area between Kirkcudbright and Castle-Douglas, the igneous mass merges into a plexus of bosses and dykes, running mainly in two directions, one across the strike and the other more or less parallel with it.

The general type of the Criffel and Dalbeattie mass varies from a hornblende-biotite granite to a quartz-diorite; the relative proportion of the constituent minerals changing throughout the area. The rock is rich in oligoclase, and augite is sometimes present. Sphene is widely distributed, being readily detected in the field with an ordinary lens. The more hornblendic varieties frequently occur near the margin of the mass.

The granite contains basic inclusions, composed of quartz-diorite, which, from microscopic examination, appear to be richer in minerals belonging to the earlier phases of consolidation. These are more commonly met with near the margin, though occasional instances are to be found even in the centre of the mass. They vary in size from a few inches to several feet in length, and in the normal granite have usually an oval form.

The normal granite and basic inclusions are alike traversed by minute veins of more acid material composed of aplite containing quartz and alkali felspar, while the broader veins merge into pegmatite. In some instances where an acid vein traverses a basic inclusion it is accompanied by a slight displacement of the inclusion, as shown in the accompanying sketch from Craignair Quarry (see fig. 1). It has further been noted, when one acid vein is traversed by a second vein of similar composition, that the earlier one is slightly displaced. These aplite and pegmatite veins traverse the granite in varying directions.

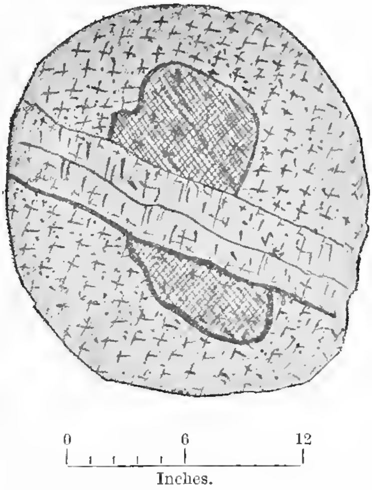

Fig. 1.—Vein of Aplite traversing Granite and Basic Inclusion, Craignair Quarry, Dalbeattie.

The granite occurs mainly in the massive form throughout this extensive area, but there are certain limited tracts where it has a marked foliated character. The latter variety is a marginal phenomenon. It does not, however, extend continuously round the border of the igneous mass, being restricted to well-defined areas; the largest of which forms a marginal belt, extending from Southwick along the east slope of Criffel to Loch Kinder and New Abbey. Again, in the extreme north-east border, this foliated variety can be traced westwards from Kirkconnel Moss by Craigbill Hill to Craigend Hill, south of Lochanhead Station. At Almorness Point, between Auchencairn Bay and the mouth of the Urr, foliated granite occurs also at the margin of the mass. As the observer passes inwards towards the centre, he finds the foliated variety of the border tract gradually to merge into the massive granite. It ought to be clearly borne in mind, however, that elsewhere for miles along the junction-line there is no trace of foliation.

The evidence obtained in the field clearly points to the conclusion that the foliation must have been superinduced on the massive granite with the basic inclusions, after it had reached its present position and after the formation of the acid veins. The phenomena may best be studied along the granite margin from Southwick to Loch Kinder. It is observable, in the case of the larger basic inclusions, that the foliation traverses the granite and basic portions in one common direction as shown in the accompanying sketch (see fig. 2). The cone-shaped inclusions have been compressed and are arranged with their long axes in the direction of foliation (see fig. 3). Indeed, in some instances, they have been flattened into lenticles that taper at the ends and measure nine inches long by about

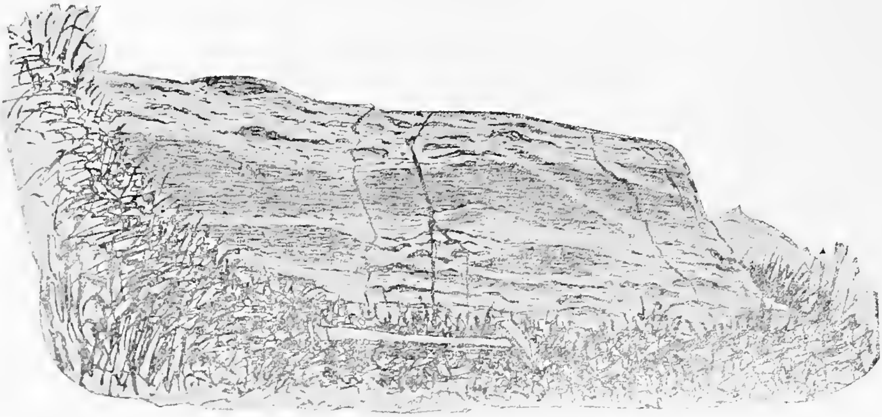

FIG. 2.—Mass of Rock showing how Granite (pale bands) and its Basic Inclusions (darker bands) have been deformed, and have assumed in consequence a common foliation, about ¼ mile north of Kells Farmhouse, Southwick.

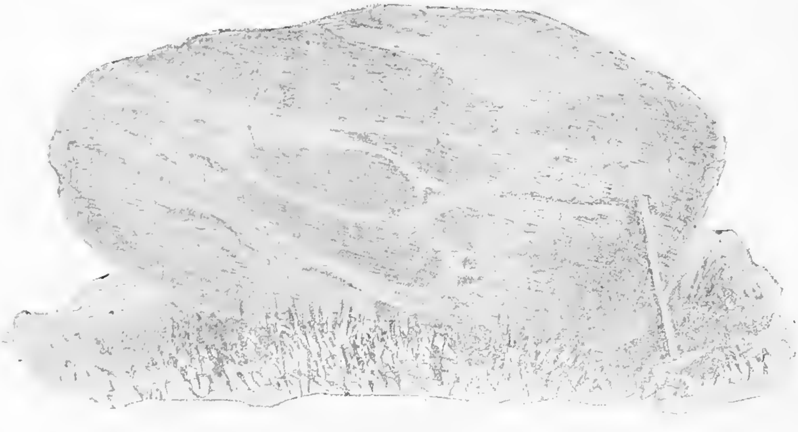

FIG. 3.—Granite (shown by paler parts), with Basic Inclusions (darker parts) traversed by one common system of Foliation-Planes, about ¼ mile north of Kells Farmhouse, Southwick.

three inches broad. Other instances have been noted where they appear as thin dark bands about six inches long, and from a quarter to half an inch broad. These examples occur on the hill slope east of Southwick, and to the north of Kells Farmhouse. Others might be quoted from the south-east of Criffel, overlooking the village of Kirkbean. These phenomena recall structures in Archæan areas in the north-west Highlands, and among the Eastern Schists in the east of Sutherland. A further examination of the border tract shows that the quartzo-felspathic veins, and the quartz veins have been foliated and granulitised, the foliation planes being independent of the direction of the acid veins. In short, the normal granite or quartz-diorite, the basic inclusions, and the aplite, pegmatite, and quartz-veins have been foliated in one common direction. The general trend of the foliation in that region is north-east and south-west, in accordance with the general strike of the Silurian rocks, the dip of the foliation planes being in the same direction as that of the altered sediments. It is obvious, therefore, that these secondary structures have been superinduced in this portion of the granite mass, by dynamic action connected with earth movements.

The microscopic characters of these foliated rocks are described in detail in that part of the Appendix which deals with the petrography of the igneous rocks. It may be sufficient to state here that they furnish evidence in support of the secondary origin of the foliation. The quartz and alkali-felspar are the constituents which yielded most readily to dynamic agencies. The yielding of these constituents dragged out the biotite and hornblende, while the oligoclase was the last to be affected.

The extreme phase of alteration of the granite is visible in a boss at the margin of the mass, about a mile to the north-east of Kells Farmhouse. It occurs almost in a line with the stone wall bounding Drumbuie Wood on the south-west side. The foliation-planes dip to the south-east and the rock is a grey granulite with felspar 'eyes,' recalling some of the structures of the deformed granite dykes in the east of Sutherland.

After the development of the foliation, the foliated granite was injected by a well-marked series of dykes of the same character and composition as some of those traversing the normal granite and the contact zone of Silurian sediments. Excellent examples of these intrusions occur on the hill slope forming the south-east spur of Criffel overlooking the Kirkbean Burn, on the east slope of the same mountain northwards to Loch Kinder, and again in the tract north-west of Drumbuie Wood. These dykes run in a north-westerly direction, and have fine-grained or chilled edges. No single instance has been observed among them of any trace of foliation.

In the north-west corner of the Map there is a small portion, amounting to several square miles, of the Cairnsmore of Fleet mass of granite. The rock is apparently of a more acid type than that of Criffel and Dalbeattie.

Dykes.—Within the belt of altered rocks surrounding the granite and far beyond these limits there is a remarkable series of dykes of different lithological types. Dykes of similar character and composition likewise traverse the massive and foliated granite, as already indicated. The latter cannot be regarded as ordinary apophyses of the granite. The phenomena connected with these later intrusions in the normal granite may be studied on Bengairn and in the district of Colvend.

These intrusions are classified by Mr Teall as follows:—1. Porphyrites; 2. Diorites; 3. Mica-traps; 4. Basalts. The members of the first group form the largest series. Possessing in most cases a compact ground mass with porphyritic plagioclase and hornblende, they are readily distinguishable from the normal granite of the region. Typical examples occur within the contact zone on the Colvend shore, between Kirkcudbright and Castle-Douglas, and to the north of Dalbeattie. Indeed, it is the common type of dykes cutting the foliated granite south-east of Criffel. Some of these contain a few large phenocrysts of orthoclase. An example of the same type has been obtained from the normal granite on the top of Bengairn (see Appendix, page 52). The members of the second group are not of common occurrence, but examples have been noted in the normal granite and in the Silurian area. Dykes of mica-trap are rare. They have been observed in the Silurian area on the Green Hill east of Meiklewood, at Nun Mill on the west bank of the Dee, on the shore south of Kirkandrews Bay, and near Ringdoo Point in the parish of Borgue. These rocks have undergone considerable alteration, which has to some extent obscured their original structure.

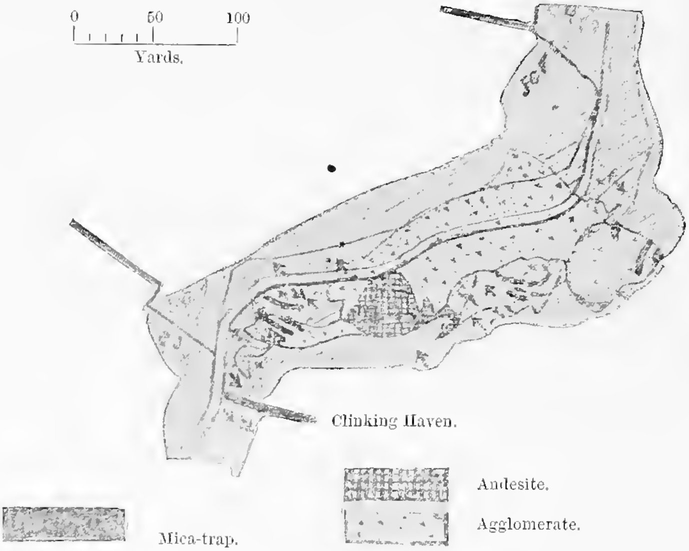

Fig. 4.—Ground Plan of Neck (Lower Carboniferous) in Silurian Rocks, shore at Nun Mill, Kirkcudbright.

Several examples of basalt dykes occur within the Silurian area. They have been noted in Kirkandrews Bay on the Borgue shore, at Long Robin on the east side of Kirkcudbright Bay, and in the Mulloch Bay west of Netherlaw Point. Under the microscope, a specimen from the last locality shows lath-shaped plagioclase, augite, and magnetite, with alteration products. One instance, occurring in the granite about a mile to the south of Lochanhead Station, is worthy of note, as the microscopic characters of the rock resemble those of many Carboniferous lavas. It has been traced for 400 yards through the granite on Craigend Hill, in an east and west direction. Under the microscope it shows "green pseudomorphs after porphyritic-olivine, together with a few augites and felspars in a ground mass of microlitic augite, plagioclase and magnetite."

Necks.—Within the Silurian area there occur examples of volcanic necks, from which igneous materials may at one time have been discharged. These are now filled with agglomerate, composed of Silurian fragments, pierced in one instance by basalt and andesite. They do not contain any fragments of Carboniferous sandstones or shales, and are probably of Lower Carboniferous age.

The best instance occurs on the shore at Nun Mill on the west side of Kirkcudbright Bay (fig. 4) where the relations to the surrounding strata are well displayed. The northern edge of the vent is situated at the point named Shoulder O'Craig, and it can be followed round the cliff to Clinking Haven. There the agglomerate truncates the edges of the Silurian rocks. It varies in character from a coarse assemblage of angular blocks of greywackes and shales to a fine tuff with a dark green base containing angular fragments of Silurian rocks. It is pierced by a mass of igneous material, of which two specimens show—one the microscopic characters of a basalt, the other, those of an andesite. The former rock displays pseudomorphs after olivine in a ground mass of lath-shaped plagioclase, granular and microlitic augite, and magnetite. These microscopic characters link the mass with the type of Lower Carboniferous lavas in the Kirkbean district. Traversing the mass of basalt and andesite there are thin veins of chrysotile about a quarter of an inch broad. The agglomerate is pierced by dykes similar in character to the larger mass just described. Dykes of mica-trap occur in the Silurian rocks and at the margin of this vent. Another neck is to be found near Ingleston about a mile from the village of Twynholm.

METAMORPHISM OF SILURIAN ROCKS.

The intense lateral pressure to which the Silurian rocks have been subjected has produced a considerable amount of cleavage among the shales of the Llandovery and Wenlock formations. The general trend of the cleavage has already been indicated (see p. 18). Along the coast, between the Fleet and the Dee, where the folding and cleavage of the strata are well seen, it is observable that the beds are intersected by numerous veins of quartz and calcite. Those of quartz vary in size from mere strings to a foot or more in breadth. In the broader veins, small cavities appear, lined with quartz crystals. Near the Needles Eye, on Colvend shore, veins of amethyst occur, as noted by Hay Cunningham.

The granite masses are surrounded by a ring of altered sediments of varying breadth and intensity of alteration. The phenomena illustrating the contact metamorphism of this region will be described in detail in a forthcoming Survey Memoir. Towards the outer limits of alteration the strata are indurated, breaking with a conchoidal fracture, and showing a dark brown colour due to the development of minute flakes of mica. This type of alteration is met with also in the region west of Screel and Bengairn traversed by the plexus of bosses and dykes of porphyrite and granite. When traced towards the granite margin, the alteration is more pronounced. In the altered grit bands, near the boundary line, biotite is abundantly developed and the quartz grains are granulitised : the flags and shales pass into mica schists, the plates of mica conforming to the wavy outline of the divisional planes.

In the more extreme phases of change, the granitic material seems to permeate the schistose rocks at the junction, as, for instance, near the south end of Barclay Hill, Colvend. Under the microscope, the rock shows micropoikilitic hornblende, biotite, quartz-felspar mosaic, and a few large turbid felspars. Again, where the quartz-diorite or granite sends veins, several inches broad, into the altered sediments, these branch off into strings, which may be in visible connection with the larger veins, or the igneous materials may appear as isolated bands or crystals in the schists (see fig. 5). These phenomena are well seen at the junction on the hill slope near Kells Farmhouse, Southwick. The microscopic examination of specimens illustrating the alternation of layers of sediment and thin branching veins of igneous materials shows that the sediment is represented by an aggregate of minute grains of a colourless mineral (felspar) and reddish-brown mica. The igneous materials are represented by turbid felspar (probably oligoclase), clear felspar (orthoclase), hornblende, and some sphene. Cataclastic structures are visible in the igneous portion of the rock.

The age of the granite mass of Criffel and its attendant metamorphism may be approximately determined. Evidence has already been adduced to prove that the granite and its apophyses traverse sediments of Llandovery, Wenlock, and Ludlow age. On the other hand, the intrusion of this igneous complex must be older than Upper Old Red Sandstone time, for strata of the latter period rest unconformably on Upper Silurian rocks pierced by apophyses of the granite. It is further apparent, from evidence to be presently described, that the sediments under which the granite lay buried must have been removed and the igneous rocks exposed, before the formation of the beds of arkose, grits, and conglomerates which are such a conspicuous feature in the Lower Carboniferous series of the Colvend and Rerwick shores.

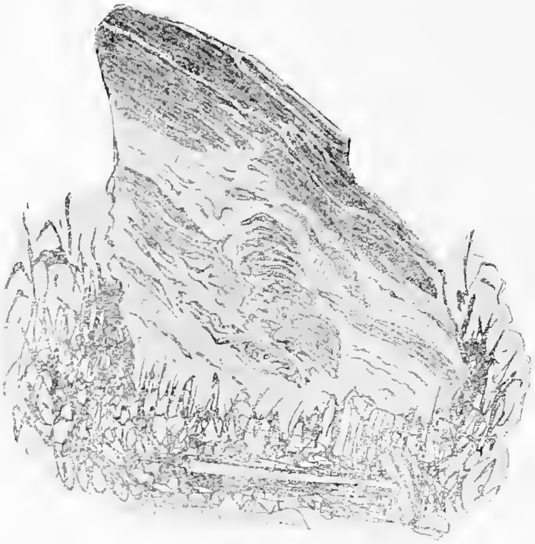

FIG. 5.—Intrusion of Granitic Material (shown by the paler parts) into altered Silurian sediments (darker parts), Hill-slope of Criffel, ¼ mile N. of Kells Farmhouse, Southwick.

UPPER OLD RED SANDSTONE.

Representatives of this system are met with in the Kirkbean district, where they underlie the contemporaneous volcanic rocks at the base of the Cement-stone series. They are poorly developed, being confined to a few localities along the margin of the volcanic area, and in some instances they have been exposed in the stream sections by the denudation of the overlying cake of bedded lavas.

In the Ladyland Burn they form a narrow fringe about fifty yards broad at the edge of the volcanic rocks. Consisting of red sandstone, red clays, and cornstones, they dip to the south at gentle angles, passing underneath the lavas. Descending the stream towards Prestonmill we find the red mudstones and shales exposed in the burn by the denudation of the lavas. Owing to the overlap of the volcanic rocks, this red sandstone series cannot be traced continuously along the margin of the lavas. But in Kirkbean Burn it reappears, forming the floor of the volcanic series : indeed at one point in the glen, within the volcanic area, the stream has cut down through both the lavas and the hardened red sandstone to the breccia that rests on the Upper Silurian rocks.

CARBONIFEROUS.

Lower Volcanic Zone.

The contemporaneous volcanic rocks underlying the Lower Carboniferous series of the Kirkbean district are the prolongations of the volcanic zone which has been traced from the sources of the Liddell and the Rule Water to Birrenswark in Annandale. They form a thin cake extending along the slopes of the hills from Torrorie to the farmhouse of Drum—a distance of three miles. They consist of lavas, sometimes slaggy and amygdaloidal, without any intercalations of volcanic tuff. A specimen of basalt lava from Kirkbean Glen shows, under the microscope, lath-shaped plagioclase, carbonates, chlorite, and magnetite.

In the Ladyland Burn, the sequence can be traced from the Upper Old Red Sandstones and marls, through the lavas to the overlying dark grey sandstones and shales of the Cement-stone series, which, at Prestonmill, dip to the south-east at an angle of 20°. From this point south-west to Torrorie they are traceable by means of small exposures in the fields. Northwards they can be followed in knobs protruding through boulder clay, to Kirkbean.

The best section occurs in the Kirkbean Glen, for about half a mile upstream, west of the village. At the base the lavas are slaggy and amygdaloidal, while the higher beds are more compact. The fissures in the volcanic rocks are filled with baked sandstone, due to the sediment having been washed into the cracks of the solidifying lava. For nearly a quarter of a mile the stream has cut through this volcanic cake and the underlying red sandstones, to the floor of Silurian rocks, which have yielded Wenlock graptolites and orthoceratites. Near the mouth of the glen at the village of Kirkbean the dark shales and grey sandstones of the Cement-stone series are brought into conjunction with the lavas by a fault.

Calciferous Sandstone Series.

The representatives of this division of the Carboniferous system occur in several detached areas : (1) in the Kirkbean district, (2) in small outliers on the Colvend shore, (3) in a narrow strip from Rascarrel Bay to White Port on the Rerwick coast.

Kirkbean District.—The Carboniferous tract in the Kirkbean district is occupied by members of the Calciferous Sandstone series. In the northern part, these strata are exposed in the streams west of Drum farmhouse, in the Spout Gill, and in the Cushat Wood. From the evidence obtained in these sections it is clear that the Cement-stone series is thrown against the Silurian rocks by a north and south fault close to the granite boundary. In the Spout Gill, hardened dark shales and sandstones are exposed at high angles, the beds being nearly vertical. Near the boundary line the sandstones and shales dip towards the fault at an angle of 66°. Similar evidence is obtained in the stream at the south end of the Cushat Wood, where the sandstones and dark shales dip away from the fault at angles varying from 40° to 66°.

The belt of low ground stretching from the margin of the lavas to the coast is covered with superficial deposits and few sections are visible. On the shore, however, between Hogus Point near Carsethorn and Southerness, there is an almost continuous section. The strata, which are there much faulted and folded, may be grouped in the following descending order:—

4. Coralline limestones of Arbigland Bay.
3. Sandstone, shales, and thin marine limestones.
2. Thirlstane sandstones.
1. Sandstone and shales with marine bands and cement-stones.

The Thirlstane sandstones may be the equivalents of the Woodcock Air and Fell sandstones of Annandale and Liddesdale.

A characteristic feature of the series is the presence of marine bands beneath the Coralline limestone, which have yielded the following assemblage of fossils:—

Aulopora ramulosa, Goldf.
Athyris ambigua, Sow.
Lingula mytiloides, Sow.
Productus semireticulatus, Mart.
Aviculopecten Geikiei, Eth. Jr.
Avicula Hendersoni, Eth. Jr.

Edmondia sulcata, Phill.
Myalina crassa, Flem.
Euomphalus acutus, Sow.
Spirorbis carbonarius, Murch.
Entomostraca.

The almost entire absence of corals and Polyzoa from these lower bands serves to distinguish them from the highest sub-division of the series in Arbigland Bay. In this bay, below high-water mark, the Coralline limestones form a symmetrical basin, their successive beds being arranged in concentric layers dipping towards the centre at gentle angles. The corals are abundant and admirably preserved. With the characteristic form, *Lithostrotion Portlocki*, are associated *Lithostrotion irregulare*, *L. basaltiforme*, *L. junceum*, *Chaetetes tumidus*, &c. The members of the underlying zone rise from underneath this trough on the north side, curving round till they run parallel with the coast beyond Borron Point.

On the south side of Arbigland Bay they reappear, the sequence being disturbed by numerous faults. At the south end of Arbigland Wood they dip seawards at angles varying from 20° to 33°. At a point about 200 yards south of Arbigland Wood they are faulted against the Thirlstane sandstones; the downthrow being to the north. From this locality southwards for a distance of a third of a mile to Powillimount, grey and yellow false-bedded sandstones run parallel with the coast, dipping eastwards at an average angle of 34°. Seawards the Thirlstane sandstones pass underneath thin limestones and shales; and near Powillimount they are associated with a thin coaly layer a few inches thick.

At Powillimount, the sequence is again disturbed by a fault with a downthrow to the south. On the south side of this fault, the sandstones and shales with marine bands overlying the Thirlstane sandstones reappear, being thrown into well marked folds. Proceeding southwards along the shore, we may trace a gradual passage downwards into a series of false-bedded sandstones and grits (Thirlstane sandstones), visible in the skerries to Southerness Point. West of this promontory, the sandstones, shales, and marine bands again appear (Locality 62 in Palæontological Section of Appendix), where they are traversed by numerous faults.

Colvend Shore.—Between Southwick and the mouth of the Urr, three outliers of Carboniferous strata occur at the base of the prominent cliff of altered Silurian rocks. They have been brought into contact with the older rocks by means of a fault which skirts the base of the cliff for several miles, and, as already indicated, gives rise to the persistent straight feature.

In the first of these outliers which occurs on the carse land, at the base of the cliff, about a mile to the west of Southwick House, the strata consist of coarse breccias, dipping E. 10° S. at angles varying from 45° to 55°. The second occurs at a distance of half a mile between Portowarren and Portling Bay, where the beds are composed mainly of a coarse arkose, derived from the disintegration of the granite. Pebbles of granite and other igneous rocks occur in the grits. These beds of arkose are associated with calcareous grits, occasional green shales, and thin limestones. From a dark calcareous bed near Portowarren Bay, the following fossils, belonging to the horizon of the marine bands in the Calciferous Sandstone series of the Kirkbean district, were obtained; *Modiola modioliformis*, *Bellerophon Urei*, and *Orthoceras*. The third outlier extends from Castle Hill to Gutcher's Isle, immediately to the east of the mouth of the Urr. In this instance, the Carboniferous rocks are faulted against a mass of granite, that pierces the altered Silurian strata and forms a prominent cliff in the bay west of Barcloy Quarry. They consist of coarse brecciated conglomerates and grits dipping south-east at angles varying from 15° to 32°. Here, also, pebbles of different varieties of igneous rocks connected with the granite are extremely abundant; with these occur fragments of greywacke and shale, and pebbles of white quartz. In a bed of friable calcareous grit in Glenstocking Quarry, close to the fault, a specimen of *Syringopora ramulosa* was obtained. From the presence of such marine organisms in the coarse sedimentary deposits of Glenstocking and Portowarren, it is evident that the marine bands of the Calciferous Sandstone series are here represented by beds which must have accumulated close to the shore. This conclusion receives further support from the evidence obtained in the area west of the Urr, now to be described.

Rerwick Shore.—From White Port to Aird's Point, east of Rascarrel Bay, the Lower Carboniferous rocks occupy a strip of ground along the shore measuring about 7 miles in length and half a mile in breadth.

At the western limit, in White Port Bay, the breccias at the base of the series rest unconformably on the Upper Silurian rocks. Here the olive Silurian shales, stained red by the infiltration of iron oxide, dip to the west of north at 60°, while the overlying basal Carboniferous breccia is inclined to the south-east at an angle of 20°. The breccia is composed mainly of angular fragments of the adjacent rocks, being succeeded by a grey brecciated conglomerate, with a large percentage of white quartz fragments. From this point round the shore to Port Mary, grey and reddish-grey grits are associated with bands of conglomerate in which the largest pebbles measure about a foot across. The unconformability is again seen in the Abbey Burn, where the Silurian shales are overlain by grey grits and breccias dipping south-east at angles varying from 15° to 20°. At

Abbey Burnfoot, in soft shales, fragments of *Eurypterus* and plant-remains were found. At Port Mary the breccias are traversed by veins of barytes exposed on the shore on the east side of the bay.

It is not improbable that these conglomerates and breccias may represent, in part, the Upper Old Red Sandstone.

From Port Mary eastwards by Orroland to Barlocco, the foregoing series passes upwards into strata containing certain marine bands which are highly fossiliferous. Lithologically, this group varies considerably from the type of the Calciferous Sandstone with marine bands in the Kirkbean district. It consists of alternations of sandstones, grits, occasional conglomerates with well-rounded pebbles, thin limestones, shales, and clays with calcareous nodules. A large assemblage of fossils has been obtained from the limestones and shales near the bathing-house below Orroland, and at the waterfall east of the bathing-house (see Palæontological Section of Appendix, Localities 56 and 57). Most of these organisms are common to the marine bands in the Calciferous Sandstone series of the Kirkbean district. The brecciated grits and conglomerates interleaved in this marine series contain pebbles of granite, and other igneous materials, with greywacke and white quartz.

At Castle Muir Point, east of Barlocco Bay, a low anticlinal fold rises in coarse conglomerates and grits with red and pale-coloured clays. The conglomerates are extremely coarse, many of the blocks measuring 2 feet across. They consist chiefly of granite and the associated igneous rocks, greywacke, and vein-quartz. The pebbles are embedded in a matrix of arkose derived from the disintegration of the igneous rocks of the district. These coarse grits, sandstones, and red clays occupy the coast north to Rascarrel Bay, where on the west side of the bay they contain fragments of lava. In certain calcareous sandstones, on the east side of the latter bay, specimens of *Athyris ambigua*, *Productus semireticulatus*, and *Aviculopecten* were found. Eastwards along the shore to Aird's Point, coarse grits, conglomerates, and sandstones occupy the coast, dipping seawards at an angle of 20°, until thrown against the Silurian rocks by a fault well seen on the shore. This fault is traceable westwards by Rascarrel Bay towards Barlocco.

PLEISTOCENE AND RECENT.

Drift and Ice-worn Rocks.

STRIATED ROCK-SURFACES.—Within the area under description, the deposits characteristic of the Glacial Period are well represented. From the finely glaciated contours of the Silurian and granitic rocks it is evident that the ice-sheet exercised a powerful influence in moulding the superficial features of the country. A glance at the Map will show that, during the period of extreme glaciation, the ice-flow must have been independent of any mass of high ground included in this district. The great centre of dispersion lay to the north-west, round the Kells and Merrick ranges, from which the ice radiated in all directions. On both sides of the Dee, north-west of Castle-Douglas, the ice-markings point in a south-east direction; but westwards, towards the valleys of the Tarff and the Fleet, the trend is south and a few degrees west of south. Similarly in the districts of Twynholm and Borgue the trend is S. and S.S.W. On the shores of Balmangan Bay, north of the Meikle Ross, the appearances presented by these ice-worn surfaces may be seen to advantage. The Upper Silurian rocks have been finely polished and carved into a succession of *roches moutonnées*, on the surfaces of which the striations indicating the direction of the ice-flow are marvellously fresh. In this neighbourhood they point S. and S. 10° W. On the east side of the Dee, at Kirkcudbright, and onwards to Auchencairn, the striæ run in a south-east direction. It is important to note that the mass of high ground round Screel and Bengairn, as well as the elevated tract in the neighbourhood of Criffel, seems to have caused a slight deflection of the ice in its south-eastward course. But it is also true that, during the extreme glaciation, when the ice-sheet attained its maximum thickness, even these elevated masses were overflowed by it. This is evident from the glaciated appearance of the hill tops, and from the occurrence of Silurian rocks in the boulder clay in the valleys on the south side of Criffel, which will be referred to presently. At the mouth of the Nith, the ice-sheet could not have been less than 2000 feet thick. Reference has already been made to the parallel granite ridges along the east side of the valley of the Urr, which have been moulded by the massive ice-sheet that crossed the district. The general trend of these ridges is N.N.W. and S.S.E., in accordance with the direction of the ice-flow indicated by the striæ.

BOULDER-CLAY.—This deposit is well represented in the district. It consists of a tough clay through which are scattered smoothed and striated stones of various sizes without any regular arrangement. Indeed, throughout the district embraced in the Map, there is no trace of stratification in this deposit, and, with a few exceptions, there is a remarkable absence of stratified sands and gravels intercalated with the boulder-clay. The matrix is generally of a clayey nature, but in the granitic areas it is more gritty and less cohesive. The manner in which the deposit varies in character according to the nature of the underlying rocks is well exemplified in various sections. On both sides of the Dee, north of Crossmichael, the colour is reddish, owing to the red or purplish tinge of the Queensberry series. Throughout the areas occupied by the Hawick and Wenlock rocks, it varies from a grey to a brown tinge, and in the granitic tracts the same varieties of shade are observable. The blocks imbedded in the clayey matrix are mainly derived from the underlying rocks, but, in addition to these, there is always a certain percentage of blocks which must have travelled for a considerable distance underneath the ice-sheet. Indeed, a detailed examination of the dispersal of the stones in the boulder-clay not only confirms the general south-easterly trend of the ice-flow in this tract of country, but also places beyond doubt that the most elevated ground must have been overflowed by the ice. In the boulder-clay sections, in the neighbourhood of Castramont, Lochinbreck, and Lawrieston, smoothed granite stones occur which have been derived from the granite mass shown in the north-west corner of the Map. In like manner, the granite area of Criffel and Dalbeattie has been invaded by blocks of the altered and unaltered Silurian rocks situated to the north-west. In the hollow drained by the Glaisters Burn, which rises on the west slope of Long Fell, and flows into the Kirkgunzeon Lane, there is a thick deposit of boulder-clay containing striated stones of different Silurian rocks, commingled with granite and other igneous materials.

It is noteworthy, also, that the proportion of these foreign blocks diminishes according to the distance from the north-west margin of the granite between Dalbeattie and Killywhan. But even on the south side of the watershed which stretches from Criffel to the Cuil Hill, the same association of foreign and local rocks is observable in the boulder-clay. On the south side of the col which connects Criffel with the Borcland Hill, a coomb-shaped hollow in the granite is filled with boulder-clay, which rises to a height of 1200 feet below the col, and 'tails off' where the 800 feet contour-line crosses the valley. The Kirkbean Burn which rises in this hollow, has cut a channel through the deposit, which may be conveniently studied in the sections exposed in the banks. In all respects this high stony clay resembles ordinary till. One noteworthy feature in it is the presence of smoothed and striated fragments of Silurian rocks, which, however, are not abundant when compared with the granite stones. Further to the west, in the Boreland Burn and its tributaries, draining the south slopes of the Cuil Hill and Thorter Fell, deep boulder-clay sections show a limited number of finely striated greywacke blocks associated with the granite stones of the district. These foreign rocks must have travelled from 4 to 6 miles, at least, across the granite tract ere they reached their present position, and they must have crossed the heights which lay in the track of the ice-flow. This conclusion receives additional support from the occurrence of ice-worn fragments of Silurian rocks on the tops of the highest elevations throughout the granitic tract, which are in all likelihood the relics of the old *moraine profonde.*

There are one or two exceptional instances of the association of sands and gravels with the boulder-clay. Close by the Farmhouse of Balig, east of Kirkcudbright Bay, a section is exposed in a pit in which a deposit of stiff brown boulder-clay, from 3 to 4 feet thick, rests on finely stratified sand, with layers of small stones. Again, near the shore at Abbey Burnfoot a deposit of stiff stony clay is seen resting on gravelly matter with occasional large stones and layers of fine water-worn gravel.

In the valleys draining the elevated tracts, the boulder-clay is invariably spread out in the form of a more or less continuous sheet through which channels have been cut by the streams. This feature is displayed in the mass of high ground round Criffel. But throughout the undulating low ground, it is generally arranged in oval ridges or 'drums' which form prominent features in certain districts. Frequently these ridges rise to a height of 100 feet above the surface of the ground at their base, and they also occur singly and in groups. They are well developed on both sides of the valley of the Dee between Parton and Castle-Douglas, and eastwards towards the valley of the Urr. The same characteristic features are presented in the districts of Twynholm and Borgue. It is worthy of note that in the valley of the Dee north of Castle-Douglas, and also in the vale of Urr, the ridges of boulder-clay are partly covered by the later accumulations of gravel.

SANDS AND GRAVELS.—This series is mainly confined to the river valleys and to the strip of low ground bordering the coast at Kirkbean. The sands and gravels rest on the boulder-clay or the solid rock, and, as a rule, the gravelly material is well rounded. They frequently occur in the form of cones or ridges, and they are no less commonly distributed as an irregular covering on the slopes of the river valleys. It is a significant fact, connected with the distribution of these gravels, that they do not maintain a uniform level when followed down the stream. On the contrary, they sink in height in accordance with the slope of the valley. In the basin of the Fleet, where they are sparsely developed, they do not rise much above the level of the 100-feet marine terrace, to which they probably belong. Along the plain which stretches from the south end of Woodhall Loch southwards by Lawrieston, and the Beoch Moor to Kirkconnel in the valley of the Tarff, there is a continuous covering of sand and gravel, averaging about a mile in breadth, and varying in height from 200 to 250 feet. This series reappears at Fellend about a mile below Kirkconnel, and fringes both sides of the Tarff to its point of junction with the Dee. It likewise steals up the hollow behind Valleyfield as far as the village of Twynholm, where it attains the level of 225 feet above the sea.

It is worthy of note that no trace of these deposits is to be met with between Tongueland and Argrennan in the valley of the Dee. Along that part of its course the river has cut a channel through solid rock, without accumulating alluvial deposits. But between Castle-Douglas and Parton the sands and gravels have a limited development. In like manner, this series can be traced along both sides of the Urr valley from the point where it enters the Map to the edge of the granite mass at Dalbeattie. Near the Old Bridge of Urr, on the left bank of the river, the gravels reach a height of 250 feet. Another series extends along the sloping ground to the east of Auchenіnnes Moss, and sweeps northwards in the direction of Southwick Station. From thence it may be followed up the slopes to Tarkerra and Bargrug, where the deposit is heaped up, in the form of kames, reaching a height of 350 feet, and sweeping southwards along the narrow valley as far as the Walltrees Moss between the Round Fell and Clawbelly Hill. An isolated patch of gravel, about a mile in length, occurs at the Glaisters, south-east of Kirkgunzeon Station, where it reaches a height of 400 feet. The members of this series cannot be traced continuously round the coast from the estuary of the Nith to the Urr. They form an irregular covering over most of the low ground between the mouth of the Drum Burn and Mainsriddle. They reappear in Sandyhills Bay, and a small patch occurs in the course of the Mid Burn near Rockcliff. Isolated patches occur on the shore at Port Mary and at Orroland, where the gravel reaches a height of 250 feet.

Erratic Blocks.—Numerous examples of erratics are to be met with throughout the area embraced in this Explanation. The evidence supplied by their dispersion seems to point to the conclusion that they have been mainly distributed during the chief extension of the ice. They are always to be found in greatest abundance in the track of the ice-sheet, as indicated by the striæ.

Boulders of granite are plentiful along the valley of the Fleet, on the hilly ground between Loch Skerrow and Twynholm, and all over the cultivated ground lying to the west of the Dee, between Kirkcudbright and Meikle Ross. One example on the Farm of Ingleston, near the village of Twynholm, contains 99 cubic feet, but the average size of the blocks is much smaller. An occasional granite erratic is to be found on the ground lying to the east of Kirkcudbright Bay and onwards to Dundrennan. In all these instances they have been derived from the great granite tract which extends from the Dee westwards to Cairnsmore of Fleet.

It is of importance to note that very few erratics of the Criffel and Dalbeattie granite are to be found on the surface to the north-west of the boundary line between Bengairn and Killywhan, and they have not been observed in the boulder-clay to the north-west of that line. One, however, occurs north of the boundary line near Cairnyard, east of Killywhan, and occasional examples are met with along the Kirkgunzeon Lane, but these are quite exceptional. No erratic of Dalbeattie granite has been noted in the valley of the Urr to the north of the igneous mass, nor in the undulating ground west of Buittle. The area occupied by the altered Upper Silurian rocks, between the mouth of the Urr and Kirkbean, is strewn with rounded boulders of pink and grey granite. A similar dispersion is indicated by the distribution of erratics derived from the mass between Bentuther Hill and Stockerton Moor, and from the numerous bosses and dykes in that neighbourhood. These are found at intervals over the cultivated tract between Kirkcudbright and the Rerwick shore. Throughout the granite area, large blocks of the same rock are strewn on the hill tops and rocky ridges, but many of these are merely due to the disintegration of the *roches moutonnées*, while others were distributed during the general and local glaciations. In the Kirkbean district some examples occur of granite boulders resting on gravel kames and on the stratified deposits close to the edge of the 50-feet beach, thereby indicating that these erratics must have been dispersed at wide intervals of time.

One of the most interesting features connected with the glaciation of the south-east part of the county of Kirkcudbright is the wide distribution of boulders of granite derived from the Criffel and Dalbeattie mass, over the north of England southwards to Wales.

MORAINES.—The deposits belonging to the later glaciation are poorly developed in the area now under consideration. In the north-west corner of the district there is a well-marked series of them along the banks of the Glengainoch Burn and its tributaries. This stream rises in the eastern slopes of Fell of Fleet, and flows into the Dee above Loch Stroan. Though the moraine heaps usually have a conical form, there are some excellent examples of terminal moraines crossing the valley; the longest measuring about 400 yards. The surfaces of the mounds are strewn with granite boulders. The morainic material consists of loose unstratified, gravelly detritus in which most of the stones are composed of granite, while a small percentage of greywacke and schist blocks is also present. Sections of moraines are met with in the railway cutting at Loch Skerrow, and to the east of the Stroan viaduct. Pits have been dug in these heaps on the north side of the railway at the latter locality. The character of the material differs widely from boulder-clay on the one hand, and from the well-rounded gravel of the kame series on the other. It is composed of loose earthy debris with subangular stones, few of which are scratched. The larger blocks embedded in the deposit consist of granite, and boulders of the same rock are found on the surface. The moraines rest directly on the finely polished surfaces of the metamorphic rocks. The absence of any well-marked series of moraines from the valleys draining the elevated ground round Criffel is worthy of note. Near the sources of some of the streams, earthy and gravelly detritus, with some striated stones is observable, which may be of morainic origin. On the west side of the Bail Hill, at a height of 600 feet, there is a group of small moraine heaps covered with granite boulders: and again, near the source of the Glaisters Burn, on the west slope of the Long Fell, some isolated mounds are met with, consisting of gravelly detritus at a height of 475 to 500 feet.

Raised Beaches.

Round the shores of the Solway, and along the banks of the different estuaries, there are well-marked terraces indicating former sea-levels. Those occurring at high levels have been much denuded, and they cannot therefore be traced for any great distance; but the lowest, or the 25-feet terrace, forms a prominent feature throughout the district. Along the banks of the Fleet a series of stratified sands and gravels can be traced northwards to Castramont, reaching a height of 100 feet, which, as above remarked, probably form part of an old sea-beach. Again, on the shore between the mouth of the Abbey Burn and Port Mary, a similar series of stratified gravels is met with, varying in height from 100 to 125 feet. Much of the gravel in the low grounds of Kirkbean likewise belongs to the same sea-margin. This high-level terrace, marking the close of the glacial series, usually contains finely laminated brick-clays, with Arctic shells, in other parts of Scotland, but in the present areas these deposits have not been observed at this level.

The 50-feet terrace also occurs in a fragmentary manner, having been cut into and worn away by the sea when the 25-feet beach was formed. A portion of it is seen at the village of New Abbey, both the village and the Old Abbey having been built on this terrace. It occurs also between Southerness and Loaningfoot, and again between West Preston and Mainsriddle. Near Southerness the plain of this ancient beach is partly obscured by blown sand drift. On the shores of Barlocco Bay a fragment of it is also displayed; the old cliff line formed by tidal action being well seen to the north of Castle Muir. Another small remnant is met with on the right bank of the Dee at Kirkcudbright, while on both sides of the Fleet at Gatehouse the remains of this terrace are still better preserved. The deposits consist mainly of finely stratified sands, gravels, and clays. In the estuary of the Nith, the brick-clays belonging to this beach are worked near Dumfries, as described in the Explanation of Sheet 9 (par. 82).

By far the best marked terrace occurs at a lower level, the average height being 25 feet, but when traced inland it gradually rises to the level of 30 or 40 feet. On the other hand, there is frequently a gradual descent to the present high-water mark. On the right bank of the Nith the 25-feet beach occurs at Kirkconnel, where it is covered by a thick deposit of peat. From Ingleston it stretches westwards to New Abbey, and at Carsethorn it steals inland to the village of Kirkbean. Between Southerness and Caulkerbush it forms a tract of carse-land, above a mile in breadth, below Southwick House, part of which is covered by recent accumulations of blown sand. Again, on the banks of the Urr below Kirkennan, and from Auchencairn northwards by Potterland Lane, strips of flat land occur at the 25-feet level, which rise in height when followed inland. Similarly on the banks of the Dee, between St Mary's Isle and Tongueland, and on the Fleet below Gatehouse, terraces are met with at this height. In all likelihood, the deposits belonging to this terrace at the mouths of these rivers are estuarine rather than marine.

The deposits, characteristic of the 25-feet beach, consist of stratified sands, gravels, and finely laminated clays. These brick-clays are exposed in the course of the New Abbey Burn near the Airds, and again at Brickhouse north of Carsethorn. Similar brick-clays occur also on the right bank of the Dee at Kirkcudbright.

Caves and Cavern Deposits.

Reference may be made here to the occurrence of caves at various localities along the shores of the Solway Firth. These recesses have been drilled in the rocky cliffs by the action of the sea, and from the position which some of them occupy above high tide mark, they furnish proof of changes in the relative position of land and sea in post-glacial time. Some of these caves are washed by the sea at high tides, while others of them are situated considerably above the high tide mark. Amongst the larger caverns, the following may be mentioned: the Piper's Cove west of Sandyhills Bay, the Barlocco Cave, Torr's Cove on the east side of Kirkcudbright Bay, the Borness Cave, and the cave in Meikle Saddling Bay below Muncraig. An interesting feature connected with the caves drilled in the Lower Silurian rocks is the abundance of carbonate of lime lining the interiors of the caverns. This feature is specially noticeable in the cave in Meikle Saddling Bay, where the roof is studded with stalactites, and the sides are coated with stalagmite.

The Borness Cave is the most important of the group, having yielded abundant osseous remains, indicating its occupation by man. It has been carefully explored by Messrs Corrie, Bruce-Clarke, and Hunt, who have examined and described its contents.[1] The floor of the cave, before any of the deposits had been removed, was about 27 feet above the high tide level; but when due allowance has been made for the thickness of the contents, it is estimated that the original floor was about 19 feet above that level. The erosion of this cavern by the sea, in all likelihood, belongs to the time of the formation of the 25-feet beach. The length of the cave, which consists of a single chamber, is about 39 feet. At the entrance the explorers encountered a large mass of stalagmite and breccia stretching from side to side. On the floor, the deposit consisted of cave-earth in which the various objects were embedded. A thin layer of stalagmite was intercalated with the cave-earth, the accumulation of the former probably indicating that for a time the cave was deserted by its occupants. The objects found in the cave are of a varied character, comprising 'bones, burnt wood (along with which are found also burnt bones), shells, grain, implements of bone, fragments of iron, a few ornaments and fragments of bronze, and a few implements of stone.' From the resemblance which many of the objects bear to those met with in the Settle Caves the explorers are inclined to refer its occupation to the Romano-British period.

Peat and Alluvium.

To the south of the carse-land between Southerness and Caulkerbush a wide expanse of marine alluvium is exposed at low tide, known by the name of the Mersehead and Barnbowie Sands. A still larger tract of similar deposits extends from the Kirkbean coast eastwards to the mouth of the Lochar Water. Along the banks of the main river-courses alluvial patches are invariably met with, as may be seen by referring to the Map. In the Fleet these strips of flat land occur to the north of Gatehouse, in the valley of the Tarff between Ringford and Compston, and again along the course of the Dee north of Castle-Douglas. A broad patch of alluvium extends from Carlingwark Loch westwards to the Dee at Threave Isle, which at one time evidently formed a lake. During heavy spates this tract is occasionally inundated at the present time. Along the banks of the Urr there are well-nigh continuous strips of alluvium, and at Dalbeattie where the Kirkgunzeon Lane unites with the Urr, the alluvial plain is about a mile in breadth. Similarly, along the course of the Kirkgunzeon Lane between Killywhan and Southwick Stations, alluvial patches occur, some of which were probably lakes. Frequently it happens that the larger streams have formed a succession of terraces indicating successive stages in the excavation of the valley. These features are well represented in the Tarff, south of Ringford, where three distinct terraces can be traced. But in addition to these terraces which have been formed by river action there are numerous minor patches of alluvium apart from the river-courses which mark the sites of lakes in post-glacial time.

In the north-western portion of the area the more important peat-mosses are met with, where they lie partly on rock and partly on drift. The slopes of the rough granite hills round Loch Skerrow possess a broken covering of peat which is rapidly wearing away. But in the hollows between the hills and ridges this deposit reaches a considerable depth. One of the largest tracts extends from Loch Skerrow southwards by Loch

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[1] See the following papers on the subject:—I. 'On a Cave containing Bones and Objects of Human Workmanship, at Borness, Kirkcudbright,' by A. J. Corrie, M.A., F.S.A. Scot.; W. Bruce-Clarke, B.A., F.S.A. Scot.; and A. R. Hunt, M.A., F.G.S. II. 'On the Osseous Remains of the Borness Bone Cave, Kirkcudbrightshire,' by W. Bruce-Clarke, B.A., F.S.A. Scot., and Randall J. Johnston, M.A.I. —*Proceedings of the Society of Antiquaries of Scotland*, vol. x., session 1873-74.

Lane to the sources of the Burnfoot Burn. Many of the flat patches between the 'drums' of boulder-clay are overgrown with peat, and in some cases it is evident that the mosses have supplanted old lakes. The transverse hollow running southwards from the moss of Edingham east of Dalbeattie to the Cloak Moss is covered with peat. At the north-east corner of Sheet 5, a small portion of the Kirkconnell Moss occurs which is continued in the adjoining Sheets 6 and 9. This moss, as already indicated, rests on the 25-feet beach, and has been reclaimed to a large extent round its outer limits.

Within the area included in this Explanation peat with roots of trees is met with at two localities, close to and even below high-water mark. Near the mouth of the New Abbey Burn, at the point where the Drumillan Burn joins it, roots of trees are exposed on the banks of the stream covered with the finely laminated clay of the 25-feet terrace. This buried forest is probably a continuation of that referred to in the Explanation of Sheet 9 which was found in the course of sinking a well at Islesteps (see paragraph 93 in that Explanation). Again in the Bridgehouse Bay west of Meikle Ross, a deposit of peat is exposed at low tide. About 100 yards below the quay at Rockvale, on the east side of the bay, the following section was passed through. On the surface lay a thin covering of sand, beneath which about 2 feet of fine blue clay was met with. This blue clay rested on a deposit of peat from 1½ to 2 feet thick, underneath which blue stony clay was pierced. The stones in this latter deposit had a glaciated appearance, and in all likelihood it is an ordinary boulder-clay. About 150 yards south-west of the quay in the centre of the bay trunks of trees are also exposed. The peat contains hazel-nuts, with leaves, twigs, and marsh plants. There can be little doubt that this is a submerged forest occupying the same position in the post-glacial series as the buried forest at Islesteps and near the mouth of the New Abbey Burn. An interesting discovery was made in connection with the sub-marine peat in Bridgehouse Bay. A pair of antlers of the red deer with part of the skull were obtained in this bay which 'have been pronounced by competent judges to be finer than any that can be obtained at the present day.'[1]

V. ECONOMIC MINERALS.

82. Building-stones.—By far the most important quarries within this area are those in the granite at Dalbeattie. They supply abundant material of excellent quality for building, paving, and monumental purposes. The stone is capable of taking on an excellent polish. The massive grits and greywackes in the Llandovery series are also used abundantly for building. The porphyrites and micro-granites of Tongueland and Loch Dougan are employed for the same purpose. The coarse grits of Lower Carboniferous age at Barcloy on the Colvend shore have been quarried for mill-stones. On the Rerwick coast, the harder beds of grit and sandstone are well adapted for building purposes.

Limestone.—Some of the bands of limestone in the Cement-stone series in the parish of Kirkbean have been formerly quarried, as for instance, near Torrorie and to the west of Southerness Point. The Coralline limestone at Arbigland and the adjoining marine bands might also be utilised.

Road-metal.—The numerous intrusive dykes connected with the granite complex and the harder bands in the Hawick rocks and the

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[1] 'On a Cave at Borness, Kirkcudbrightshire' (*Proceedings of the Society of Antiquaries of Scotland*, vol. x.).

Queensberry grits have been employed for this purpose. At present the Dalbeattie granite is being largely used for the manufacture of granolithic pavement.

BRICK-CLAYS.—At Brickhouse near Carsethorn, in the parish of Kirkbean, and again on the right bank of the Dee at Kirkcudbright, certain dark clays have been worked for brick-making. These finely laminated clays belong to the 25-feet beach. Similar deposits at this level, near Kirkconnel and New Abbey, might be employed as brick-clays.

IRON.—Several veins of hæmatite occur in this area, chiefly round the margin of the granite. One occurs at Craigend, east of Loch Arthur, the direction of the vein being E. 17°–25° N. It is traceable for a distance of half a mile in the midst of the granite. A second vein is found on the top of Auchenfad Hill, the direction of which is N. 12° W. The most important one, which for a time was extensively worked, is situated at Auchenleck, to the north-west of Auchencairn. Latterly, this mine has been abandoned. This ore occurs in mammillated or botryoidal form, excellent specimens being obtainable at the mine. A thin vein is met with at the head of Glen of Screel in the contact zone of Silurian rocks round the granite.

COPPER.—About a mile and a half south-east of Gatehouse, the Enrick mine occurs which was sunk in search of copper. This mine has long been abandoned. According to Hay Cunningham, the ores found in the vein at this place were composed of the green carbonate of copper and sulphate of copper with iron pyrites. Attempts have been made to obtain copper from a vein in the Isle of Hestan, and at other localities on the Colvend shore.

BARYTES.—Veins of Barytes occur in the district of Auchencairn near Barlocco. Two important and nearly parallel veins, formerly worked, are situated close to the Farmhouse of Barlocco, trending W. 6° to 8° N.

FUEL.—The various peat mosses in the north-west portion of the Map supply fuel for local use, and the same material is used in other districts within the Map. The Kirkconnel Moss, a portion of which is shown in the north-east corner of Sheet 5, furnishes peat of excellent quality. No coal seams are associated with the Cement-stone series of the Kirkbean district.

APPENDIX.

A. PETROGRAPHY OF THE IGNEOUS ROCKS.

By J. J. H. Teall, F.R.S.

I. The Large Granitic Masses.

Criffel and Dalbeattie Mass.—The prevailing type of rock in this mass is a moderately coarse-grained grey granite or quartz-diorite, essentially composed of biotite, hornblende, oligoclase, an alkali-felspar and quartz; iron-ores, apatite, and sphene are almost always present as accessory constituents, and a pale-coloured augite is occasionally found. The biotite is of the type usually occurring in granites. The basal plane is often well developed, but the prismatic planes are very imperfect, and it is rare to find a section showing even an approach to the hexagonal form. The pleochroism is very intense, varying from yellowish or reddish-brown to nearly opaque. The first stage in the alteration of this mineral is seen in the replacement of the deep brown, characteristic of the β and γ axes, by a green colour; and this may occur without any change in the colour, for rays vibrating parallel to the a axis. The final stage of alteration, both in the biotite and hornblende, is the formation of chlorite and epidote.

The hornblende, like the biotite, is not markedly idiomorphic, though traces of the prismatic faces and the clino-pinacoid may occasionally be observed. The colour of the hornblende in the normal rock is green, but in the more basic modifications and in the dioritic inclusions greenish-brown and even brown varieties may sometimes be observed.

The dominant felspar in all the rocks, except those which represent the acid veins, is a plagioclase allied to oligoclase in composition. It is white in the hand-specimen, and frequently shows a somewhat pearly lustre on the striated cleavage faces. Idiomorphism is a marked feature of the plagioclase, so that it evidently belongs to an early phase in the consolidation of the magma. A zonal structure may frequently be seen, and this is most marked in the more basic varieties of rock. The external portions of the zoned individuals are frequently more acid than the central parts; but there is no rigid law as to the increase of acidity from centre to margin. Narrow zones of a basic felspar may recur again and again in one and the same individual (6565).[1] Inclusions are comparatively rare in the plagioclase.. Both plagioclase and alkali-felspar become turbid by the development of minute scales of a micaceous mineral.

The alkali-felspar contains both potash and soda, and is rich in the latter alkali. It never shows any trace of idiomorphism, but forms, together with quartz, the matrix or ground-mass, if that term may be applied to a granitic rock, in which the other constituents are embedded. The extinction is often wanting in sharpness, and in a few cases microcline structure has been observed. The alkali-felspar may be easily distinguished from the oligoclase, when both are unaltered, by its lower refractive index and by the absence of crystalline form.

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[1] The figures within brackets in this division of the Appendix refer to the numbers of the thin slices of rocks in the collection of the Geological Survey.

Quartz occurs in irregular grains and as ophitic patches. In the more basic rocks, and in the inclusions, the interstitial character of the quartz is seen in the most marked manner; small patches wedged in between the idiomorphic constituents often extinguish simultaneously over a wide area. The mineral is rich in inclusions containing bubbles.

The accessory constituents do not require detailed description. The sphene is widespread, and may often be detected in the hand specimen. Under the microscope it is seen to be deeply coloured, pleochroic, and idiomorphic. It is very abundant in some of the inclusions. The augite deserves more than a passing mention. It is of the pale-green or nearly colourless variety characteristic of the augite-granites, and usually occurs as a core in hornblende. In some of the more basic rocks it becomes sufficiently abundant to deserve recognition as an essential constituent.

Biotite, hornblende, augite when present, and oligoclase belong to the earlier phases of consolidation; quartz and alkali-felspar to the final stages. The relative proportions of the different constituents vary in different parts of the mass, and it is doubtful whether the prevailing type of rock is a hornblende-biotite-granite or a quartz-diorite of the tonalite-type. In any good exposure, such as that seen at the granite-quarries near Dalbeattie, the normal granite or quartz-diorite is seen to contain basic inclusions, and to be traversed by acid veins. The basic inclusions, so far as they have been examined, always consist of a quartz-diorite richer in the minerals which belong to the earlier phases of consolidation, and poorer in quartz and alkali-felspar than the main mass of the rock. Sphene and apatite are especially abundant in many cases. The acid veins, on the other hand, consist almost entirely of quartz and alkali-felspar. The narrow veins are formed of a fine-grained aplite; but the broad veins assume the character of pegmatite, and frequently show the graphic intergrowth of quartz and felspar. These broad veins may sometimes be broken down the median plane, so as to disclose the presence of drusy or miarolitic cavities containing crystals of smoky quartz. A section through one of the pegmatitic veins in the Craignair Quarry (6596), shows the presence of a narrow band of nearly pure quartz running through the middle of the vein. The main mass of the vein is formed of quartz and alkali-felspar, sometimes intergrown so as to form a coarse variety of micropegmatite. Oligoclase and biotite occur as accessory constituents. The alkali-felspar occasionally shows the structure of microperthite; but microcline-structure is absent. The following table gives the specific gravity of each of the rocks occurring in the Craignair Quarry :—

Acid vein, ...	2·60
Normal granite, ...	2·66
"	2·67
Basic inclusion, ...	2·77
"	2·71

So far we have been referring only to the massive rocks. As a type of the foliated rocks we may select a specimen from Criffel (1217). This is a medium-grained gneissose rock. The ferro-magnesian constituents form somewhat ill-defined flaser round phacoids of felspar or of quartz and felspar. Sphene is easily recognisable with a lens. Under the microscope the essential constituents are seen to be biotite, hornblende, oligoclase, alkali-felspar, and quartz. A pale green augite (·4 mm.) occurs as a core in one of the patches of hornblende. Brown idiomorphic sphene occurs in crystals of considerable size (·3 to ·75 mm.). The alkali-felspar shows occasionally a distinct microcline-structure, and contains inclusions of oligoclase and quartz. Small patches of felspar, intergrown with vermicular quartz, are present, and also one or two grains of a mineral somewhat doubtfully referred to orthite. The interstitial movement which has resulted in the production of foliation, and which is proved by the field-evidence to have been produced by earth-stresses operating after the rock had reached its present position, and after the formation of the acid veins, has not affected all the constituents alike. The quartz and alkali-felspar which, as we have already seen, were the last constituents to solidify, are those which have yielded most to the deforming stresses. They show signs of crushing, and frequently pass into thin micro-crystalline or even crypto-crystalline streaks, which wind round the comparatively uncrushed crystals of oligoclase. The distribution of the ferro-magnesian constituents has been modified by the movement. Instead of being irregularly distributed through the rock they tend to form flaser in association with the micro-crystalline aggregate of quartz and alkali-felspar. The oligoclase has been little if at all affected by the movement. These facts clearly prove that the minerals which yield most readily to the deforming forces are those which consolidate last. It is highly probable that the pressure acted before the rock-mass had actually cooled.

Two specimens taken from a large block occurring about half a mile north by east of Kells Farmhouse near Southwick (6572 and 6573) represent the effects of deformation in a more extreme form. The rock loses the gneissose character, and finally passes into a grey granulite. The secondary micro-crystalline aggregate forms a much larger proportion of the main mass of these rocks, and cataclastic structures are strongly marked.

The foliation not only affects the normal hornblende-granite or quartz-biotite-diorite, but also the veins of aplite and the basic inclusions, which are exceptionally abundant near the junction (6576, 6589, and 6574). Even the quartz-veins are foliated (6575). In all cases the foliation maintains the same general direction. The foliated veins of aplite are largely composed of the secondary micro-crystalline aggregate of quartz and felspar, and the large irregular grains of alkali-felspar, which have escaped crushing, show strain-phenomena under crossed nicols. The fact that the foliation in these veins has no reference whatever to the direction which they take is a striking proof that it cannot be due to fluxional movement during intrusion. It must be the result of dynamic forces operating after the intrusion of the granite, and after the formation of the veins. A section, prepared from a specimen collected at a point about a quarter of a mile north of Kells Farmhouse (6589), has been cut through the junction of an acid vein with the normal granite. The junction line is nearly at right angles to the direction of foliation, which is seen to pass from one rock to the other without a break.

Cairnsmore of Fleet mass.—This mass occupies only a small portion of the north-west corner of the Sheet. It is represented in the Survey collection of microscopic slides by two specimens (1221 and 1223). The one, from the railway cutting near the viaduct over the Little Water of Fleet, is a moderately coarse-grained rock composed of biotite, muscovite, one or two grains of hornblende, oligoclase, and microcline. The oligoclase is white in the hand specimen and the microcline pink, so that the two felspars are easily distinguishable. The general structure of the rock and the order of consolidation of the constituents are the same as in the granite of the Criffel and Dalbeattie mass. The microcline is abundant and well characterised. It occurs in large irregular interstitial masses, and contains inclusions of idiomorphic oligoclase and sphene. The other specimen, taken from a hill about six miles north of Gatehouse-of-Fleet, is a moderately coarse-grained biotite-granite also containing interstitial microcline; but in this case the two felspars cannot be distinguished in the hand specimen by a difference in colour. The section contains a few patches of vermicular quartz. These two specimens are more acid than the normal rock of the Criffel and Dalbeattie mass. Hornblende is rare or absent, biotite less abundant; quartz and alkali-felspar, on the other hand, more abundant. The occurrence of typical microcline, muscovite, and vermicular quartz are all points of interest serving to connect the rocks of this mass with the more acid granites.

II. Rocks occurring for the most part as Dykes.

1. PORPHYRITES.

Dykes abound in Sheet 5. They occur not only in the sedimentary rocks but also in the granitic masses, and the same petrological types are found in both areas. The vast majority of dykes are formed of rocks to which the term porphyrite has been applied. This term has hitherto been employed in a different sense in the publications of the Geological Survey, and a word or two of explanation is therefore necessary. Recent research has established the fact that the so-called porphyrites which occur as lavas in association with Palæozoic sediments are merely altered andesites. The continued use of the term in its old sense is therefore undesirable, and will accordingly be dropped. The word may, however, be conveniently employed in accordance with the usage adopted by American Petrographers (Prof. J. P. Iddings, 'The Eruptive Rocks of Electric Peak and Sepulchre Mountain,' *Twelfth Annual Report of the U. S. Geological Survey*, 1890–1891) for rocks of the type now under consideration. Such rocks occur for the most part as dykes, sills, and laccolites. They bear the same relation to the andesites that the porphyries do to the liparites.

These rocks are, as a rule, markedly porphyritic in structure. Plagioclase, hornblende, and biotite commonly occur as phenocrysts; quartz is occasionally found; orthoclase is very rare. The ground-mass is usually compact. The rocks vary in colour from grey to red; the latter tint being characteristic of the most highly altered varieties. The proportion of phenocrysts to ground-mass is liable to considerable variation; some rocks containing so little ground-mass as to resemble granites; others containing so few phenocrysts as to have the character of felsites. These extreme types are, however, comparatively rare.

In the typical rocks of the group, plagioclase is always the most conspicuous phenocryst, both on account of its abundance and of the size of the individuals. It occurs in single crystals, in crystalline groups, and as crystal fragments. Twinning on the Carlsbad–, pericline– and albite-plan, may often be observed. The individuals are often beautifully zoned, and by employing the Becke-effect it can frequently be demonstrated that narrow zones of a highly refractive and therefore basic felspar, are repeated several times in a single individual. The plagioclase is liable to the micaceous type of decomposition, and many rocks are so highly altered that the optical characters of the mineral can no longer be observed.

Orthoclase phenocrysts have not been identified with certainty in any of the microscopic sections, but one or two large, irregular grains, measuring half-an-inch or more across, were observed in a dyke from the south-east spur of Criffel.

The phenocrysts of hornblende and biotite are not so large as those of plagioclase. The hornblende is usually of the green type common in the granites and quartz-diorites, but a brown variety has been observed in one or two instances. As compared with the hornblende of the granite, it is remarkable for the perfection of its crystalline form. The faces of the prism and of the two vertical pinacoids are often present. Twinning of the common type may frequently be observed. The biotite is also remarkable for the perfection of its crystalline form. It occurs in hexagonal tablets, but in other respects resembles the biotite of the granites and quartz-diorites.

Quartz, when present as a phenocryst, possesses the same characters as the quartz of the porphyries. It occasionally shows an approach to the dihexahedral form, but as a rule occurs only as corroded grains. It contains inclusions with bubbles.

The ground-mass varies in different rocks. In some cases the minerals which occur as phenocrysts—plagioclase, hornblende, and biotite—may all be recognised together with quartz and alkali-felspar; in others the constituents of the ground-mass cannot be definitely determined, on account of the small size of the individuals and the confused nature of the crystallisation. Micro-poikilitic, micro-pegmatitic, and in one case spherulitic structures, have been observed. It is highly probable that quartz and alkali-felspar enter largely into the composition of this part of the rock.

It follows, from the above description, that there is very little difference in composition between the dykes of this type and the granitic rocks of the Criffel and Dalbeattie mass. This is confirmed by the following table of specific gravities :—

One mile N.N.E. of Red Bank Farm (6584), Dyke in granite,	2·65
Three-quarters of a mile E.S.E. of the top of Screel,	2·657
One mile N. of Dalbeattie (1262),	2·67
Near the summit of Ben Gairn (6578),	2·67
North of Croft-Head ; six miles north of Dalbeattie (1233),	2·65

It is probable, therefore, that the structural differences between the porphyrites and the hornblende-granites or quartz-diorites are due to differences in the conditions under which the magmas consolidated. If we suppose that an intrusion of the granitic magma took place in dyke form after the greater part of the hornblende, biotite, and plagioclase had separated out, we shall have a satisfactory explanation of the difference in structure between the porphyrites and the granitic rock. In applying this theory, however, it must be remembered that dykes of the type now under consideration occur not only in the sedimentary rocks but also in the granitic masses. Moreover, dykes are found in the foliated area unaffected by the foliation. Such dykes cannot be regarded as in any way representing apophyses of the granite. They belong to a later phase of igneous activity. The source of supply was probably the same as that from which the main igneous mass was derived ; but if so, it must have been tapped at a time when crystal building had proceeded to a considerable extent.

One fact tells somewhat against the view suggested above, and that is the not unfrequent occurrence of quartz and the occasional presence of orthoclase amongst the phrenocrysts of the porphyrites. In the granitic masses these minerals invariably belong to the final stage of consolidation.

The difficulty, however, may not be serious, for the quartz is almost always intensely corroded, and both minerals have rather the aspect of foreign constituents.

2. DIORITES.

The typical representatives of this group are medium or fine-grained dark-coloured crystalline rocks essentially composed of hornblende and a plagioclase felspar. In some specimens the hornblende may be clearly recognised with a lens in the form of long slender prisms. These rocks are denser than the porphyrites, the specific gravity ranging from 2·68 to 2·81. The hornblende is often seen to be of a deep brown colour under the microscope. It may be either idiomorphic or ophitic with respect to lath-shaped plagioclase. The idiomorphic hornblende is occasionally zoned (1269). Green hornblende is also present, and this may arise from the alteration of the brown variety, or, as seems probable in some cases, from the alteration of an original pyroxene. Twinning is not unfrequent.

The felspar, which is generally turbid, may occur in forms giving lath-shaped sections or as irregular grains which fit together so as to form the matrix in which the hornblende is embedded. Sometimes there is a little interstitial quartz, but this mineral never forms any large portion of the rock. Biotite is sometimes present. Apatite is often abundant in the form of slender prisms; iron ores are scarce or altogether absent. Chlorite, epidote, and sometimes carbonates, occur as alteration products.

Those rocks in which the hornblende is present in the form of slender prisms, belong to the camptonite division of the lamprophyres (Rosenbusch).

3. MICA-TRAPS.

The specimen from Greenhill, east of Meiklewood, is a dark-coloured rock, composed of numerous tablets of brown mica, embedded in a compact matrix. Under the microscope the mica is seen to possess the usual characteristics of that mineral as it occurs in mica-traps. The tablets are thin in proportion to their breadth, their margins are often more deeply coloured than the central parts, and the absorption for rays vibrating at right angles to the vertical axis is far less marked than it is in the biotite which occurs in the granites. The mineral is biaxial, with a very small optic axial angle. Biotite is the only phenocryst which has preserved its original characters, but there are pseudomorphs in quartz or quartz and carbonates after some other mineral—possibly augite. The groundmass of the rock is composed of small scales of biotite, felspar, carbonates, magnetite, and apatite. The felspar forms the matrix in which the other constituents are embedded. It does not show multiple twinning, and, as the refractive index is lower than that of the balsam in which the section is mounted, it is probably orthoclase. Magnetite occurs in small crystals and grains which are uniformly scattered through the section. The carbonates, as is so frequently the case in comparatively unaltered rocks of this type, cannot be attributed to the decomposition of any one mineral.

The specimen from Nun Mill is purplish in colour, and much more altered than the one above described. It is composed of biotite, pseudomorphs in carbonate after phenocrysts of augite (?), maguetite, and felspar. The felspar is altered and stained with ferric oxide, so that its precise character cannot be determined.

Both rocks are probably minettes.

III. List of Rocks and Microscopic Sections from Sheet 5 in the Collection of the Geological Survey.

I. ROCKS FROM THE LARGE GRANITIC MASSES.

A. Criffel and Dalbeattie Mass.

1. *Massive Rocks.*

Rock.	Locality.	Remarks.
Hornblende - biotite - granite. (1219)	Craignair Quarry, Dalbeattie.	Hornblende scarce.
Hornblende - biotite - granite. (6564)	Do.	Contains an inclusion of quartz-diorite very rich in sphenes and apatite. Apatite and iron - ores occur as inclusions in sphene.
Aplite. (6566)	Acid vein in granite, Oldham Quarry, 1½ miles south of Dalbeattie.	Essentially composed of quartz and alkali-felspar; that is of the constituents which formed last in the normal granite. Oligoclase and biotite present as accessories.
Quartz-biotite-diorite. (6565)	Inclusion in granite, Craignair Quarry, Dalbeattie.	Zoned porphyritic plagioclase. Narrow zones of basic felspar many times repeated in a single individual. Large plates of ophitic quartz. Sphene and apatite.
Hornblende - biotite - granite. (3648)	Dalbeattie.	Sphene and apatite. Alkali-felspar fairly abundant in large interstitial plates
Quartz-diorite. (1227)	Near top of Bengairn, 5 miles south of Castle-Douglas.	
Augite-diorite. (1218)	Top of Bengairn, 5 miles south of Castle-Douglas.	Hornblende sometimes contains cores of augite.

Rock.	Locality.	Remarks.
Quartz-augite-diorite. (1220)	West slope of Bengairn, 5 miles south of Castle-Douglas.	Augite well represented. Large plates of ophitic quartz.
Coarse-grained quartz-diorite, associated with finer grained patches of biotite-diorite. (6567)	⅔ mile east by north of Bengairn; basic portion at margin of main mass.	Dark coloured rock. The coarse-grained portion contains brown or greenish hornblende, and shows an approach to a basic diorite of the camptonite type.
Quartz-augite-biotite-diorite, in contact with fine grained granulitic rock. (6568)	Do.	The granulitic rock is composed of small grains of augite, felspar and magnetite, with large irregular plates of biotite showing micropoikilitic structure.
Quartz-biotite-diorite and hornblende-biotite-granite. (6569)	East slope of Bengairn.	
Quartz-biotite-diorite. (6570)	⅔ mile east by north of Bengairn. Main mass near junction.	In addition to the compact hornblende there is also a little pale green uralitic hornblende, probably after augite.
Quartz-diorite. (1256)	Top of Bentuther Hill, 5¼ miles south of Castle-Douglas.	Small quantity of interstitial orthoclase.
Hornblende-biotite-granite. (1231)	Loch Hill, Loch Kinder.	Quartz scarce.
Hornblende-biotite-granite. (1232)	West of Saltflats, Colvend Shore.	
Hornblende-biotite-granite, with inclusion of quartz-diorite. (1216)	Shore cliffs, about 200 yards east of Netherhowe Cottages, 6 miles south-east of Dalbeattie.	Biotite, hornblende, oligoclase, with quartz and alkali-felspar as interstitial matter.

Rock.	Locality.	Remarks.
Quartz-biotite-diorite. (1222)	Barclay Hill, Colvend.	Cores of augite in hornblende, sphene, apatite, and iron ores.
Quartz-biotite-diorite. (1228)	Do.	
Biotite-granite. (1224)	At Saltflats, Colvend Shore.	Quartz very scarce.
Quartz-biotite-diorite. (1225)	Midhill, Screel, 5 miles south of Castle-Douglas.	
Quartz-biotite-diorite. (1279)	Auchenfad Hill, New Abbey.	
Biotite-granite. (1229)	Barclay Hill, New Abbey.	

2. *Foliated Rocks.*

Rock.	Locality.	Remarks.
Gneissose hornblende-biotite-granite. (1217)	Criffel, Solway.	Pale green augite inclosed in hornblende.
Gneissose hornblende-biotite-granite. (6571)	North of Kells Farm, Southwick, Criffel Mass.	Flaser of microcrystalline quartz and felspar. Mechanical effects seen in the biotite and hornblende. Plagioclase not much affected. Sphene.
Aplite-vein in gneissose hornblende-biotite-granite. (6576)	¼ mile north of Kells Farm, Southwick.	Both rocks traversed by a common foliation.
Aplite-vein in gneissose hornblende-biotite-granite. (6589)	Do.	Do.
Highly sheared biotite-granite. (6572)	About ½ mile north by east of Kells Farm.	Main mass a microcrystalline aggregate of quartz and felspar, with small scales of biotite arranged in 'schlieren.' A few large and sometimes broken crystals of oligoclase.

Rock.	Locality.	Remarks.
Grey granulite, the result of more intense shearing of a hornblende-biotite-granite. (6573)	About ½ mile north by east of Kells Farm.	Similar to the last. Pressure fluxion round the more or less broken oligoclase-crystals strongly marked. Hornblende,- with augite core.
Acid vein in basic inclusion ; both rocks traversed by a common foliation. (6574)	Do.	Acid vein mainly composed of quartz and alkali-felspar in large irregular grains, associated with a microcrystalline mosaic.
Quartz vein in gneissose hornblende-biotite granite. (6575)	Do.	The vein is composed of microcrystalline quartz, and is foliated parallel with the granite.
Gneissose rock. Crushed granite (?) (1273)	Criffel.	A few large and more or less idiomorphic crystals of oligoclase in a microcrystalline matrix showing good fluxion. Flaser of biotite in matrix.
Sheared biotite granite. (1274)	Loch Arthur Farm, 6 miles N.N.E. of Dalbeattie.	
Sheared biotite granite, and inclusion. (1275)	Drumjohn, Kirkgunzeon, 4 miles north-east of Dalbeattie.	
Folia of diorite alternating and blended with metamorphosed sediment. (6577)	At junction of Criffel Mass, about ¼ mile north of Kells Farm.	Pressure fluxion in diorite. Sediment represented by a fine-grained aggregate of reddish-brown mica, quartz, and felspar.

B. CAIRNSMORE OF FLEET MASS.

Rock.	Locality.	Remarks.
Muscovite biotite-granite. (1221)	Railway cutting near Little Water of Fleet Viâduct.	Microcline. Hornblende present, but scarce.
Biotite-granite. (1223)	Laugheughie Hill, 6 miles west of Gatehouse-of-Fleet.	Microcline. Vermicular quartz.

II. ROCKS OCCURRING FOR THE MOST PART AS DYKES.

Porphyrites.

Rock.	Locality.	Remarks.
Porphyrite. (1276)	Shore cliffs at Nether Clifton, 6 miles south-east of Dalbeattie.	Large turbid felspars in groundmass of small scales of biotite, felspar, and quartz.
Porphyrite. (1277)	Grennan Hill, Colvend.	Zoned porphyritic plagioclase in a groundmass of biotite, felspar, and quartz. Pale hornblende.
Hornblende-biotite-porphyrite. (1237)	East of Sandyhills, 5½ miles south by east of Dalbeattie.	Micro-to crypto-crystalline groundmass, showing flow structure.
Hornblende-biotite-porphyrite. (1247)	Craigneuk Point, Colvend Shore.	Good type.
Hornblende-biotite-porphyrite. (1250)	Lot's Wife, Southwick Shore.	
Hornblende-biotite-porphyrite. (1243)	Do.	Rock granitic in appearance. Groundmass present in small quantity. Microcrystalline.
Quartz-biotite-porphyrite. (6592)	Dyke near Gutchers Isle, Colvend Shore, 6 miles south of Dalbeattie.	Red rock; much decomposed. Chlorite and epidote. Quartz scarce.
Quartz-hornblende-biotite-porphyrite. (1246)	Upper Tower of Glenstocking, Colvend Shore.	Quartz phenocrysts scarce.
Quartz-biotite-porphyrite. (1248)	Ladyland Glen, 2 miles west of Kirkbean.	Pink rock; highly altered.
Quartz-biotite-porphyrite. (1249)	Rockcliffe, Colvend.	
Quartz-hornblende-biotite-porphyrite. (1230)	Criffel. Dyke in granite.	Phenocrysts of quartz, hornblende, biotite, oligoclase in a microcrystalline groundmass.

Rock.	Locality.	Remarks.
Quartz - hornblende-biotite-porphyrite. (6581)	Third dyke cutting granite, south-west of top of Bengairn.	Brown hornblende and biotite in groundmass.
Quartz - hornblende-biotite-porphyrite. (1244)	East of Netherlinkens, 5 miles N.N.E. of Kirkcudbright.	Pink rock. Felspars too much altered for precise determination.
Biotite-porphyrite. (1257)	West face of Bentuther, 5 miles south of Castle-Douglas.	Pink rock; granitic in appearance. Micro - pegmatitic groundmass.
Hornblende - biotite - porphyrite. (1245)	Argrennan Farm, 4 miles north of Kirkcudbright.	Pink rock ; highly altered.
Quartz - hornblende-biotite-porphyrite. (1240)	East of Hartburn, 4 miles north-east of Kirkcudbright.	Do.
Quartz - biotite - porphyrite. (1241)	Roadside north of Sypland, 3¾ miles N.N.E. of Kirkcudbright.	Do.
Hornblende - biotite - porphyrite. (1254)	Between Bentuther and Tunhill, 5 miles south of Castle-Douglas.	The rock contains very little groundmass, and thus resembles a granite in the hand specimen.
Hornblende - biotite - porphyrite. (1255)	Hill slope east of Bentuther, 5½ miles south of Castle-Douglas.	Grey rock.
Hornblende - biotite - porphyrite. (1236)	Kelton Kirk, 1½ miles south of Castle-Douglas.	
Hornblende - biotite - porphyrite. (6593)	Dyke near Slagnaw, 2½ miles south of Castle-Douglas.	Biotite and hornblende replaced by chlorite.
Hornblende - biotite-porphyrite. (1239)	North of Midpark, Bridge of Dee, 3 miles south-west of Castle-Douglas.	Altered pink rock

Rock.	Locality.	Remarks.
Quartz - biotite - porphyrite. (6584)	Dyke in granite. Hill, 1 mile N.N.E. of Red Bank Farm.	Phenocrysts scarce; groundmass compact. Sp. gr., 2·65.
Quartz hornblende-biotite-porphyrite. (6585)	Common type of dyke in granite, ⅔ miles south-east of Criffel.	Groundmass holocrystalline, and in part micrographic.
Hornblende - biotite-porphyrite. (1238)	Hill, 1 mile north of Dalbeattie, Dyke.	Microcrystalline groundmass, containing small scales of biotite. Flow structure. Biotite and hornblende dragged out into flaser.
Hornblende - biotite - porphyrite. (1271)	Do.	Do.
Quartz hornblende-biotite-porphyrite. (1242)	Do.	Aggregates of quartz grains.
Quartz - hornblende-biotite-porphyrite. (1234)	Barskeoch Hill, 2 miles west of Dalbeattie.	Fragment of biotite-diorite attached.
Hornblende - biotite-porphyrite. (1235)	Hill west of Auchengate, 2 miles north-west of Dalbeattie.	Holocrystalline groundmass including small idiomorphic felspars and small individuals of biotite and hornblende.
Quartz - hornblende-biotite-porphyrite. (6582)	Second dyke, 8 yards wide, south-west of top of Bengairn. In granite.	Microcrystalline groundmass.
Hornblende - biotite-porphyrite. (1233)	North of Crofthead, 6 miles north of Dalbeattie.	Pink rock. Ferro-magnesian minerals replaced by chlorite. Epidote and carbonates present. Spherulitic structure in groundmass.
Porphyrite. (6595)	South of Chapmanton, 1 mile N.N.W. of Castle-Douglas.	Compact pink felsitic rock. Ferro-magnesian minerals scarce.

Rock.	Locality.	Remarks.
Hornblende - biotite - porphyrite. (1270)	Railway cutting near Stroan Viâduct, New Galloway Station.	
Porphyrite. (1272)	Laughenghie Hill, 6 miles north of Gatehouse of-Fleet.	Turbid felspar (in part at least plagioclase) in a coarse microcrystalline groundmass, containing flakes of reddish brown mica.
	Diorites.	
Diorite. (1251)	Needle's Eye, Colvend Shore.	Brown hornblende, both idiomorphic and ophitic. Lath-shaped plagioclase. Interstitial quartz. Chlorite, epidote, and green hornblende.
Diorite. (1252)	Do.	Do. Sp. gr., 2·68.
Biotite diorite (Camptonite). (6594)	Dyke near Castle Hill Point, Colvend Shore, 6 miles south of Dalbeattie.	Small prisms of brownish hornblende, biotite, and pyroxene (?) in a matrix of felspar, with a small quantity of interstitial quartz. Apatite abundant. Chlorite and epidote present. Black fine-grained rock. Sp. gr., 2·81.
Diorite (Camptonite). (6583)	Dyke in granite, summit of Bengairn.	Slender prisms of green (altered) hornblende in a felspathic matrix.
Biotite-diorite. (1978)	West slope of Bengairn, 5 miles south of Castle-Douglas.	Biotite and green (altered) hornblende in a matrix largely composed of lath-shaped plagioclase.
Diorite. (1267)	East of Meikle Kirkland, 6½ miles north of Dalbeattie.	Similar to 1251. Sp. gr., 2·76.
Diorite. (1268)	Near West Glenarm, 5 miles north of Dalbeattie.	Do.

Rock.	Locality.	Remarks.
Diorite (Camptonite). (1269)	Near Slagnaw, 2½ miles south of Castle-Douglas.	Prisms of brownish green hornblende, sometimes zoned, in a matrix of turbid felspar.

Appendix to the Diorites.

Rock.	Locality.	Remarks.
Biotite-diorite (?). (6587)	Thin dyke in granite of Barclay Hill, Colvend.	Compact rock without phenocrysts. Small scales of biotite very abundant; aggregates of pale green hornblende. Felspar.
Biotite-diorite. (6588)	Do.	Similar to the last, but containing more hornblende. Augite present.

Mica-traps.

Rock.	Locality.	Remarks.
Minette. (1261)	Green Hill, east of Meiklewood.	Dark coloured rock; comparatively unaltered. Phenocrysts of biotite in a compact matrix.
Minette (?). (1262)	Shore near Nun Mill.	Dark purplish rock; decomposed.

Basalts and Andesites.

Rock.	Locality.	Remarks.
Basalt. (1218*b*)	Dyke, Mullock Bay.	Rock more or less decomposed. Lath-shaped plagioclase, augite, magnetite, and dull yellowish-green alteration products.
Basalt. (1260)	Dyke, east of Boatman's house, Mullock Bay.	Do.
Olivine-basalt. (1218*a*)	Dyke in granite, Craigend, Killywhan, 7 miles N.N.E. of Dalbeattie.	Green pseudomorphs after Porphyritic olivine, together with a few augites and felspars in a groundmass of microlitic augite, plagioclase, and magnetite.
Olivine-basalt. (1259)	Do.	

Rock.	Locality.	Remarks.
Andesite. (1253)	Dyke; shore, Balcary Point, south of. Auchencairn.	Porphyritic plagioclase, with inclusions similar to those commonly found in andesitic lavas. Groundmass of small scales of biotite, felspar, and grains of iron-oxide.
Andesite (?). (1258)	On shore near Nun Mill.	Phenocrysts of altered felspar in purple matrix.
Basalt. (1264)	Near Nun Mill.	Highly altered.
Basalt. (1265)	Do.	Pseudomorphs after olivine, in a groundmass of lath-shaped plagioclase. Granular, and microlitic. Augite and magnetite.
Basalt. (1266)	Kirkbean Glen, Lava.	Lath-shaped plagioclase, carbonates, chlorite, and magnetite (Melaphyre).

Contact Rocks.

Rock.	Locality.	Remarks.
Contact rock. (6590)	4 yards from junction, south-end of Barclay Hill.	Micropoikilitic hornblende. Reddish-brown biotite. Micropoikilitic quartz. Quartz-felspar mosaic. A few large turbid felspars. Probably an admixture of granitic and sedimentary material.
Contact rock. (6591)	¼ mile north of Kell's Farmhouse.	Pale green hornblende, biotite, pyroxene, a few large individuals of felspar, in part oligoclase, and microcrystalline quartz and felspar. The specimen contains one narrow greenish-grey band, composed of granular pyroxene, quartz, and felspar.

Rock.	Locality.	Remarks.
Contact rock. (6577)	¼ mile north of Kells Farmhouse, Southwick.	Granitic material injecting and impregnating sediments. Sediment represented by an aggregate of minute grains of a colourless mineral, and small scales of reddish-brown mica. The colourless grains are for the most part felspar. The igneous material is represented by a coarse-grained aggregate of turbid felspar (probably oligoclase), clear felspar (orthoclase), and hornblende with some sphene. Cataclastic structures are well shown in the igneous portion of the rock, and cracks in the turbid felspar have been filled up with orthoclase and hornblende. This appears to show that the deformation took place at a high temperature ; probably before the mass had cooled down. Bands, rich in hornblende, alternate with the metamorphosed sediment, and some of the large irregular individuals contain numerous colourless grains, similar to those which occur in altered sediments (micropoikilitic structure).

B. PALÆONTOLOGICAL NOTES. By B. N. Peach, F.R.S.

The fossils of Llandeilo-Caradoc and Llandovery age, enumerated in the following lists, were collected by Mr A. Macconochie at different times, dating from the year 1876. A few were added by Messrs Peach, Horne, and Macconochie during successive visits made to the Black Shale outcrops, and all have been determined by Mr Peach.

The Wenlock and Ludlow fossils were chiefly collected by Mr James Bennie in 1874, and determined by Mr Robert Etheridge, jun., while he acted as Palæontologist to the Scottish Survey. In 1876 Mr A. Macconochie made a small additional collection from the fossiliferous grits of Balmae, which was named by Mr Peach. The brachiopods of these collections were afterwards examined by the late Mr Thomas Davidson, F.R.S.

The present lists are compiled from these sources.

All the Carboniferous fossils enumerated in the list were collected by Mr A. Macconochie, and named by Mr Peach.

I. LIST OF LOCALITIES

FROM WHICH FOSSILS HAVE BEEN OBTAINED BY THE GEOLOGICAL SURVEY IN SHEET 5 AND THAT PART OF SHEET 6 WHICH LIES W. OF THE RIVER NITH.

The numbers are those by which the Localities are denoted in the succeeding List of Fossils.

Llandeilo-Caradoc and Llandovery.

(' Glenkiln-Hartfell and Birkhill ' Shales.)

1. Tottlehams Burn at Knoll, above wood, 4½ miles N. of Castle-Douglas.
2. ,, at mill, at road 4½ miles N. of do.
3. ,, at stone dyke, E. of Nether Kilquhanity, do.
4. ,, at edge of wood above mill, do.
5. Urr Water, a few yards S. of junction of Tottlehams Burn.
6. Streamlet, Mailie's Walls, ½ mile S. of Trowdale, 3½ miles N. of Castle-Douglas.
7. Trowdale Glen, 450 yards above road, 3½ miles N. of do.
8. ,, 100 yards above road, 3½ miles N. of do.
9. In field, 400 yards S.W. of Mailie's Walls, Trowdale, do.
10. ,, 700 yards S.W. of Mailie's Walls, Trowdale, do.
11. ,, 650 yards E. of Balgerran, 3½ miles N. by W. of do.
12. ,, a few yards W. of Kilnotrie, 3½ miles N. by W. of do.
13. ,, 900 yards S.S.E. of Balgerran, 3½ miles N. by W. of do.
14. ,, ½ mile S.E. of Balgerran, 3½ miles N. by W. of do.
15. ,, 600 yards E.S.E. of Balgerran, 3½ miles N. by W. of do.
16. ,, S. of Bellymack, Lawrieston, 5 miles W. by N. of do.
17. Burn, ½ mile S.W. of Dunnance Farm, 6 miles W. by N. of do.
18. Dunnance Farm, Lawrieston, 6 miles W. by N. of do.
19. River Dee, near junction with Ken, 1½ miles E. of New Galloway Station.
20. Tarff Water at Coal Heugh, 5 miles W.S.W. of Castle-Douglas.
21. Tarff Glen, opposite Laigh Lairdmannoch, 5 miles W.S.W. of do.
22. Little Barlay Burn, 2 miles N.N.E. of Gatehouse-of-Fleet.

Llandovery

('Queensberry and Hawick' Rocks.)

23. S. slope of Culcaigrie Hill, 4½ miles E. by N. of Gatehouse-of-Fleet.
24. Burn, 150 yards E. of Benjarg Wood, 1¼ miles E.N.E. of do.
25. Quarry near wood, 500 yards S.W. of Mailie's Walls, Trowdale.
26. Railway Cutting at Halketleaths Mill, Castle-Douglas.
27. At Railway Station, Castle-Douglas.
28. Shore, 300 yards N. of Torrs Point, E. Side, Kirkcudbright Bay.

Wenlock and Ludlow (?).

29. 300 yards S. of Bathing House, E. side of Kirkcudbright Bay.
30. Shore, immediately N. of Longrobin, ,, ,,
31. ,, S. of Longrobin, ,, ,,
32. ,, below word 'bught' on 1-inch map, ,, ,,
33. ,, immediately S. of Witch Wife's Haven, ,, ,,
34. ,, at Raven's Nest, ,, ,,
35. ,, N. side of Torrs Point, ,, ,,
36. ,, S. of do., ,, ,,
37. ,, S. of Gauger's Loup, ,, ,,
38. ,, S. of word 'Sapphire' on 1-inch map, ,, ,,
39. ,, S. of Dirk Hatterick's Cave, ,, ,,
40. ,, S. of Torrs Cove Bay, ,, ,,
41. ,, S. of Red Rock, ,, ,,
42. ,, immediately N. of Balmae Haven, ,, ,,
43. ,, ,, S. of do., ,, ,,
44. ,, S. of Shawhole, W. side of Kirkcudbright Bay.
45. ,, N. side of Balmangan Bay, ,, ,,
46. ,, E. side of Manor Hole, do., ,, ,,
47. ,, Meikle Ross.
48. ,, S. of Sugar Loaf, E. side of Meikle Ross.
49. ,, opposite Richardson's Rock.
50. ,, Fallbogue Bay, W. side of Meikle Ross.
51. ,, E. side of Howell Bay, E. of Kirkcudbright Bay.
52. ,, Gipsy Point (North band of Conglomerate). ,, ,,
53. ,, ,, (South band of do.). ,, ,,
54. ,, ,, (from Limestone Nodules). ,, ,,

Carboniferous—Calciferous Sandstone Series.

55. Rascarrel Bay, near Auchencairn.
56. Shore, near Bathing House, Orroland, Dundrennan.
57. ,, at Waterfall, E. of Bathing House, do.
58. Abbey-burnfoot, Dundrennan.
59. Near Portowarren Bay, Colvend, Dalbeattie.
60. Glenstocking Quarry, do.

Carboniferous—Calciferous Sandstone Series—Sheet 6.

61. Foot of Kirkbean Glen.
62. Shore, W.S.W. of Southerness Point, Arbigland.
63. ,, S. of Thirlstane, do.
64. ,, near Gardeners Cottage and Borron Point, do.

II. LIST OF FOSSILS.

In the following List of Organic Remains, the formations and beds are arranged in ascending order.

Llandeilo-Caradoc.

(‘Glenkiln-Hartfell’ Shales.)

Class, etc.	Name.	Locality Number.
Amorphozoa,	Radiolaria,	1, 7, 8, 9, 10, 13.
Hydrozoa,	Cœnograptus explanatus.—*Lapw.*	1.
	,, gracilis,—*Hall.*	1, 2, 7, 8, 9, 10, 11.
	,, nitidulus.—*Lapw.*	1, 7.
	,, pertenuis.—*Lapw.*	1, 7.
	,, surcularis.—*Hall.*	1.
	,, *Sp.*	11.
	Didymograptus superstes.—*Lapw.*	1, 2, 6, 7, 9, 15.
	,, *nov. Sp.*—with disc,[1]	9.
	,, serratulus.—*Hall.*	1.
	Thamnograptus typus.—*Hall.*	9.
	Diplograptus bimucronatus.—*Nich.*	1, 6, 10.
	,, dentatus.—*Brongn.*	1.
	,, euglyphus.—*Lapw.*	9.
	,, foliaceus.—*Murch.*	1, 2, 3, 7, 9, 10, 11, 12, 15.
	,, (Hallograptus) mucronatus.—*Hall.*	1.
	,, (Cryptograptus) tricornis.—*Carr.*	1, 6, 7, 8, 9, 10, 12.
	,, truncatus.—*Lapw.*	19.
	,, Whitfieldi.—*Hall.*	1, 7, 9, 10.
	,, *Sp.*	1.
	Climacograptus bicornis.—*Hall.*	1, 7, 8, 9, 10, 11, 12.
	,, ,, var peltifer.—*Lapw.*	13, 15.
	,, caudatus.—*Lapw.*	2, 3, 12.
	,, cœlatus, var antiquus.—*Lapw.*	1, 7, 9, 11.
	,, Schärenbergi.—*Lapw.*	2, 5.
	,, *Sp.*	10.
	Glossograptus Hincksii.—*Hopk.*	1, 9
	Retiolites fibratus.—*Lapw.*	2.
	Clathrograptus cuneiformis.—*Lapw.*	1, 7, 11.
	Dicranograptus Clingani.—*Carr.*	2.
	,, Nicholsoni.—*Hopk.*	1, 2, 3.
	,, ramosus.—*Hall.*	1, 5.
	,, tardiusculus.—*Lapw.*	1.
	,, ziczac.—*Lapw.*	15.
	,, *Sp.*	10.
	Dicellograptus anceps.—*Nich.*	19.
	,, Forchhammeri.—*Geinitz.*	1, 2, 6, 7.
	,, flexuosus.—*Lapw.*	1, 6.
	,, Moffatensis.—*Carr.*	1, 3, 6, 7, 8, 11, 12.
	,, patulosus.—*Lapw.*	1, 6, 7.
	,, sextans.—*Hall.*	1, 2.
	,, *Sp.*	1.
	Corynoides calicularis.—*Nich.*	10.
Brachiopoda,	Acrotreta Nicholsoni.—*Dav.*	15.
	Siphonotreta micula.—*M‘Coy.*	1, 11.
	Bivalve crustacean,	2.

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[1] The presence of the disc at the initial point suggests a close affinity between Didymograptus and Tetragraptus, and the probable descent of the former from the latter.

Llandovery.

(‘Birkhill’ Shales.)

Class, etc.	Name.	Locality Number.
Hydrozoa,	Diplograptus acuminatus.—*Nich.*	4, 16, 17, 18, 19, 20, 22.
	,, (Petalograptus) palmeus. —*Barr.*	18.
	,, tamariscus.—*Nich.*	17, 19, 22.
	,, vesiculosus.—*Nich.*	18.
	,, *Sp.*	22.
	Dimorphograptus confertus.—*Nich.*	16, 17, 18, 19.
	,, elongatus.—*Lapw.*	4.
	,, Swanstoni.—*Lapw.*	17.
	,, *Sp.*	14, 18, 22.
	Climacograptus innotatus.—*Nich.*	16.
	,, normalis.—*Lapw.*	4, 14, 16, 17, 18, 19, 20, 22.
	,, *Sp.*	19.
	Retiolites perlatus.—*Nich.*	17.
	,, ,, var,	17.
	,, *Sp.*	24.
	Monograptus attenuatus.—*Hopk.*	17, 18, 19.
	,, gregarius.—*Lapw.*	16, 17, 19, 22.
	,, ,, with gonophore attached,	19.
	,, jaculum.—*Lapw.*	17.
	,, leptotheca.—*Lapw.*	17.
	,, lobiferus.—*M‘Coy.*	17, 18, 19, 22.
	,, Sedgwicki.—*Portl.*	21.
	,, tenuis.—*Portl.*	16, 17, 18, 19, 22.
	,, triangulatus.—*Hark.*	17, 22.
	,, *Sp.*	21, 22.
	Dawsonia campanulata.—*Nich.*	17, 18, 19.
	Siculæ of Graptolites,	4, 16, 19.
Crustacea,	Discinocaris Browniana.—*Woodw.*	17.
Brachiopoda,	Lingula striata.—*Sow.*	17.

Llandovery.

(‘Queensberry’ and ‘Hawick’ Rocks.)

Class, etc.	Name.	Locality Number.
Hydrozoa,	Petalograptus ovato-elongatus.—*Kurch.*	25.
	,, palmeus.—*Barr.*	25.
	Monograptus Becki.—*Barr.*	23, 25.
	,, exiguus.—*Nich.*	23, 24.
	,, Halli.—*Barr.*	25.
	,, Sedgwicki.—*Portl.*	21.
	,, tenuis.—*Hopk.*	25.
	,, attenuatus.—*Hopk.*	25.
	,, turriculatus.—*Barr.*	25.
	Retiolites.—*Sp.*	24.
Crustacea,	Aptychopsis minus. — *Barr* (like glabra. —*Woodw.*).	25.
Incertæ sedis,	Protovirgularia Harknessi.—*M‘Coy.*	26, 27, 28.
	,, *Sp.*	26, 27.
	Worm Tracks ?	23, 26, 28.

Wenlock and Ludlow (?).

(a) *Graptolite Shales.*

Class, etc.	Name.	Locality Number.
Hydrozoa,	Crytograptus Murchisoni.—*Carr.*	44.
	Monograptus colonus ?—*Barr.*	35, 43, 48, 49, 51.
	,, Flemingii.—*Salter.* !.	29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 40, 41, 42, 43, 45, 50.

Class, etc.	Name.	Locality Number.
Hydrozoa,	Monograptus priodon.—*Barr.*	30, 31, 33, 43, 44, 45, 46.
	,, Riccartonensis.—*Lapw.*	31.
	,, vomerinus.—*Nich.*	51.
	,, *Sp.*	39, 42.
	Retiolites Geinitzianus ?—*Barr.*	45, 50.
	Dictyonema.—*Sp.*	37.
Cephalopoda,	Orthoceras annulatum.—*Sow.*	33.
	,, ,, var fimbriatum.—*Sow.*	37.
	,, politum.—*M'Coy.*	35.
	,, tenuicinctum.—*Portl.*	37, 43.
	,, subundulatum.—*Portl.*	33, 36, 37, 42, 43.
	,, *Sp.*	31, 32, 33, 38, 41, 42, 45, 47.
Crustacea,	Aptychopsis oblata.—*Jones.*	45.
	Ceratiocaris.—*Sp.*	37.
	Discinocaris (Carapace, allied to),	31, 40.
	(?) Trinucleus Benniei.—*Eth., Jnr.*	36.
Incertæ sedis,	Dictyocaris.—*Sp.*	51.

(b) *From Fine Conglomerate Bands near Little Balmae.*

Actinozoa,	Favosites.—*Sp.*	53.
	Heliolites.—*Sp.*	53.
	Petraia bina.—*Lonsd.*	52, 53.
	,, elongata.—*Phill.*	53.
	Stenopora fibrosa.—*Goldf.*	52, 53.
	Syringopora.—*Sp.*	53.
Polyzoa,	Ptilodictya.—*Sp.*	53.
Brachiopoda,	Leptæna sericea.—*Sow.*	52, 53.
	Orthis calligramma.—*Dalm.*	52.
	,, Bouchardi.—*Dav.*	52.
	,, *Sp.*	52.
Lamellibranchiata,	Pterinea.—*Sp.*	52, 53.
Gasteropoda,	Murchisonia.—*Sp.*	53.
Echinodermata,	Encrinite stems,	52, 53.
Annelida,	Cornulites.—*Sp.*	53.
Crustacea,	Phacops caudatus.—*Brünn.*	52.
	Trilobite remains,	53.

(c) *From the Limestone Nodules in Shale at Gipsy Point and Rueberry Castle.*

Brachiopoda,	Athyris.—*Sp.*	54.
	Atrypa (allied to A. hemispherica).—*Sow.*	54.
	Leptæna transversalis.—*Wahl.*	54.
	Rhynchonella.—*Sp.*	54.
	Strophomena.—*Sp.*	54.
Lamellibranchiata,	Ctenodonta.—*Sp.*	54.
	Cucullella.—*Sp.*	54.
	Orthonota.—*Sp.*	54.
Gasteropoda,	Bellerophon acutus.—*Sow.*	54.
	,, trilobatus.—*Sow.*	54.
	Loxonema.—*Sp.*	54.
	Murchisonia obscura.—*Portl.*	54.
Pteropoda,	Hyolithes (like H. aduncus of *Barr.*),	54.
Cephalopoda,	Orthoceras Etheridgei.—*Blake.*	54.
	,, *Sp.*	54.

Carboniferous.

(Calciferous Sandstone Series.)

Plantæ,	Fern stems,	58.
	Stumps of trees,	58.
Actinozoa,	Aulopora (Syringopora) ramulosa.—*Goldf.*	56.
	,, ,, *Sp.*	56.

Class, etc.	Name.	Locality Number.
Brachiopoda,	Athyris ambigua.—*Sow.*	55, 56.
	,, expansa.—*Phill.*	56.
	,, *Sp.*	56.
	Camarophoria crumena.—*Mart.*	56, 57.
	Productus semireticulatus.—*Mart.*	55, 56.
	,, ,, var Martini.—*Sow.*	56, 57.
	Rhynchonella pleurodon.—*Phill.*	57.
	Spirifera trigonalis, var bisulcata.—*Sow.*	56, 57.
Lamellibranchiata,	Aviculopecten.—*Sp.*	55.
	Edmondia.—*Sp.*	57.
	Modiola Macadami.—*Portl.*	56.
	,, modioliformis.—*Eth.*, *Jnr.*	56, 59.
	Myalina crassa.—*Flem.*	56, 57.
	,, lamellosa.—*De Kon.*	56.
	,, sublamellosa.—*Eth.*, *Jnr.*	56.
	Pteronites angustatus.—*M'Coy.*	56.
	Schizodus Salteri.—*Eth.*	55, 56, 57.
	,, ,, (elongated variety),	55.
Gasteropoda,	Bellerophon Urei.—*Flem.*	56, 59.
	Capulus (Platyceras) angustus.—*Phill.*	56.
	Euomphalus carbonarius.—*Sow.*	57.
	,, *Sp.*	56, 57.
	Loxonema constricta.—*Mart.*	56.
	,, *Sp.*	56, 57.
	Murchisonia (large form),	56.
	Naticopsis (Natica)plicistria.—*Phill.*	56, 57.
	,, *Nov. sp.*	56.
	Pleurotomaria Yvani.—*Lév.*	56.
	,, *Sp.*	56, 57.
	Turbo.—*Sp.*	56.
Cephalopoda,	Nautilus biangulatus.—*Sow.*	56.
	Orthoceras.—*Sp.*	56, 59.
Crustacea,	Eurypterus,	58.
Pisces,	Rhizodus (scales of),	55, 56.
	Fish jaw with teeth,	56.
	Palatal teeth of placoids?	56, 57.

Calciferous Sandstone Series—Sheet 6.

Actinozoa,	Chætetes tumidus.—*Phill.*	64.
	Favosites parasitica.—*Phill.*	64.
	Clisiophyllum turbinatum.—*M'Coy.*	64.
	Lithodendron affine.—*Flem.*	64.
	,, irregulare.—*Phill.*	64.
	,, junceum.—*Flem.*	64.
	Lithostrotion basaltiforme.—*Flem.*	64.
	,, cylindricum,	64.
	,, Macoyanum.—*M. Edw.*	64.
	,, Portlocki.—*M. Edw.*	64.
	Stenopora arbuscula.—*Goldf.*	64.
	Aulopora (Syringopora) campanulata.—*M'Coy.*	64.
	,, ,, gigas.—*M'Coy.*	64.
	,, ,, ramulosa.—*Goldf.*	63, 64.
	Syringopora cylindrica,	64.
	Zaphrentis cylindrica.—*Scouler sp.*	64.
	,, *Sp.*	64.
Polyzoa,	Ceriopora interporosa.—*Phill.*	62, 64.
	Fenestella (Glauconome) elegans.—*Y. & Y. Sp.*	64.
	,, *Sp.*	63, 64.
Brachiopoda,	Athyris ambigua.—*Sow.*	62, 63, 64.
	,, Royssi.—*Lév.*	64.
	Camarophoria crumena.—*Mart.*	64.
	Chonetes Buchiana.—*De Kon.*	64.
	,, Laguessiana.—*De Kon.*	64.
	,, polita.—*M'Coy.*	64.

Class, etc.	Name.	Locality Number.
Brachiopoda,	Crania quadrata.—*M'Coy.*	62, 64.
	Discina nitida.—*Phill.*	62.
	Lingula mytiloides.—*Sow.*	62, 63.
	Orthis Mitchelini.—*Lév.*	64.
	Productus giganteus.—*Mart.*	64.
	,, longispinus.—*Sow.*	64.
	,, punctatus.—*Mart.*	62, 64.
	,, scabriculus.—*Mart.*	64.
	,, semireticulatus.—*Mart.*	62, 63, 64.
	,, undatus.—*Defr.*	64.
	Rhynchonella pleurodon.—*Phill.*	64.
	Spirifera cuspidata.—*King.*	62.
	,, lineata.—*Mart.*	62.
	,, ovalis.—*Phill.*	64.
	,, pinguis.—*Sow.*	64.
	,, trigonalis, var bisulcata.—*Sow.*	62, 64.
	Spiriferina cristata.—*Schl.*	62, 64.
	Streptorhynchus (Orthotetes) crenistria.—*Phill.*	62, 64.
	Terebratula hastata.—*Sow.*	64.
Lamellibranchiata,	Aviculopecten cœlatus.—*M'Coy.*	63.
	,, dissimilis.—*Flem.*	64.
	,, elongatus.—*M'Coy.*	64.
	,, Geikiei.—*Eth., Jnr., M.S.*	63, 64.
	,, interstitialis.—*Phill.*	63.
	,, like A. macrotis.—*M'Coy.*	63, 64.
	,, plano-radiatus.—*M'Coy.*	64.
	,, *Nov. sp.*	62, 64.
	Avicula Hendersoni.—*Eth. Jnr.,*	63, 64.
	,, *Nov. sp.*	64.
	,, *Sp.*	61, 63, 64.
	Edmondia sulcata.—*Phill.*	63, 64.
	,, *Sp.*	62.
	Leptodomus clavatus.—*M'Coy.*	61, 63.
	,, costellatus.—*M'Coy.*	64.
	Modiola Macadami.—*Portl.*	62.
	,, modioliformis.—*Eth., Jnr.*	64.
	,, *Sp.*	64.
	Myalina crassa.—*Flem.*	63, 64.
	,, lamellosa.—*De Kon.*	64.
	Nuculana.—*Sp.*	63.
	Pteronites angustatus.—*M'Coy.*	62.
	,, sulcatus.—*M'Coy.*	64.
	Sanguinolites iridinoides.—*M'Coy.*	62, 64.
	,, plicatus.—*Portl.*	64.
	,, variabilis.—*M'Coy.*	64.
	Schizodus Salteri.—*Eth.*	62, 64.
	,, (Axinus) axiniformis.—*Phill.*	64.
	Solenopsis.—*Sp.*	64.
Gasteropoda,	Bellerophon decussatus.—*Flem.*	64.
	,, hiulcus.—*Sow.*	64.
	Dentalium priscum.—*Goldf.*	62, 64.
	,, *Sp.*	64.
	Euomphalus acutus.—*Sow.*	63, 64.
	,, carbonarius.—*Sow.*	64.
	,, *Sp.*	64.
	Loxonema rugifera.—*Phill.*	64.
	,, large smooth.—*Sp.*	64.
	Naticopsis (Natica) plicatula,	64.
	,, plicistria.—*Phill.*	64.
	,, lyrata.—*Phill.*	64.
	Capulus (Platyceras) angustus.—*Phill.*	62.
Pteropoda,	Conularia quadrisulcata.—*Sow.*	62.
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REFERRING TO THE GEOLOGY OF THE REGION UNDER DESCRIPTION.

1814. 'Notes on the Geognosy of the Criffel, Kirkbean, and the Needle's Eye, in Galloway,' by Professor Jameson; *Memoirs of the Wernerian Soc.*, vol. iv., p. 541.

1843. 'Geognostical Description of the Stewartry of Kirkcudbrightshire,' by R. H. Cunningham; *High. Soc. Trans.*, new series, vol. viii., p. 697.

1843. 'Remarks on the Geology of the Island of Little Ross, Kirkcudbrightshire,' by Thomas Stevenson; *Edin. New Phil. Jour.*, vol. xxxv., p. 83.

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1869. 'Notes on the Geology of Southerness, Kirkcudbrightshire,' by W. Jolly; *Trans. Geol. Soc. Edin.*, vol. i., p. 278.

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1879. 'Observations on *Roches Moutonnées*, and other Points of Geological Interest in the Valley of the Urr, Kirkcudbrightshire,' by Alexander Somervail; *Trans. of the Geol. Soc. Edin.*, vol. iii., p. 247.

1889. 'On the Ballantrae Rocks of South of Scotland, and their place in the Upland Sequence,' by Professor Lapworth; *Geol. Mag.*, Decade **III.**, vol. vi., pp. 20 and 59.

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